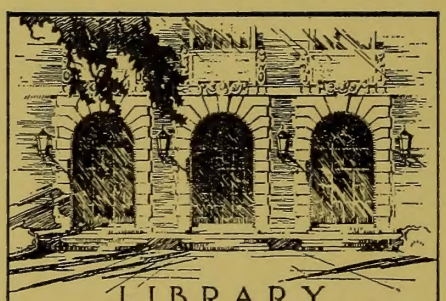

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QUARTERLY TECHNICAL PROGRESS REPORT

January, February, March 1967

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DEPARTMENT OF COMPUTER SCIENCE · UNIVERSITY OF ILLINOIS · URBANA, ILLINOIS

QUARTERLY TECHNICAL PROGRESS REPORT

January, February, March 1967

Department of Computer Science
University of Illinois
Urbana, Illinois 61801

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1. CIRCUIT RESEARCH PROGRAM

(Supported in part by the Office of Naval Research under Contract Nonr-1834(15).)

Summary

Lawrence Ryan outlines the specifications of C.R.T. and photomultiplier for the Paramatrix slide scanner. An analysis of the optical deflection equipment for the Photoconductive Matrix is presented by Dick Koo. In the area of Random Sequence Coding John Esch and Chushin Afuso discuss and analyze designs for a subtracter of synchronous random pulse sequences. Geomatrix is being extended in scope by Bill Steiner to encompass more complex types of display. Finally, Howard Schweitzer reports on preliminary experiments using field-effect transistors to perform analog multiplication.

1.1 PARAMATRIX (Project No. 01)

1.1.1 General

This project aims at replacing the present manual switch input to Paramatrix by a slide scanner system allowing electro-optical transfer of a transparent slide image into the Paramatrix system.

1.1.2 Electro-Optical Equipment

As described in the previous QTPR (October-December 1966) the slide is positioned between a C.R.T. screen and a photo-multiplier tube. Evaluation of the most suitable units available has now been completed and the chosen C.R.T. and photo-multiplier are on order.

1.1.3 C.R.T. Considerations

Paramatrix has a relatively high scanning rate, (1 to 10 μsec, depending on system speed), thus requiring a C.R.T. phosphor with time constant relatively long compared with these speeds. A P-16 phosphor (decay time 50 μsec) has been selected.

Due to the speeds required in the scanning system it was decided to use electrostatic deflection. However, due to peripheral defocusing with this system a tube face much larger than the required operating area is essential, pointing to the 5DBP-16 as a suitable choice. This single gun tube, while possessing adequate resolution has the added advantage of high deflection sensitivity (25 to 35 volts/inch) thus making possible all-transistorized circuitry.

Having decided on this tube with its blue P-16 phosphor, a photomultiplier has to be used due to the poor high frequency response of semiconductor light sensitive devices. An RCA 931A photomultiplier tube, having an S-4 response was found to be compatible with the P-16 emission.

Lawrence Ryan.

1.2 PHOTOCONDUCTIVE MATRIX (Project No. 02)

1.2.1 Light Deflector

The optical system for scanning a photo-resistor matrix in television fashion is currently being developed. Two moving coil reflecting galvanometers are employed, mounted as illustrated in Figure 1. M_1 and M_2 are fixed first surface mirrors ensuring that the beam strikes the galvanometer mirrors at the desired angle and giving parallel incident and emergent beams in the static condition. GM1 and GM2 are the galvanometer mirrors mounted with axes at right angles to each other, allowing the emerging beam to scan a sheet in the X-Z plane, as indicated.

Both fixed and angularly oscillating mirrors are so positioned that in the rest position the light path is abcdeg. The lens collimates the beam, reflected from GM1.

The incident beam is dimensioned such that it converges with angle ϕ at point A on the focal plane of L_1 (Figure 2). Rotation of GM1 will cause the node point at A to shift to B which will be off the focal plane. For small angles of rotation, i.e., AB$\ll$AC, the error will probably be negligible, as shown below, and the beam will be considered to remain collimated. From Figure 2 it is seen that the centers of the two beams will for practical purposes pass through a fixed point O on the optical axis of the lens, such that

$$LO = \frac{LC}{AC} \cdot f$$

where f is the focal length of the lens. The emerging beamwidth then is $f.\phi$. O in Figure 2 is thus considered the center of a virtual source emitting light in direction ψ, where

$$\psi = \frac{f}{AC} \cdot w$$

GM2 now is placed with its reflecting plane centered at O and by the orthogonal movement of GM1 and GM2 a scanning motion can be imparted to the emerging beam.

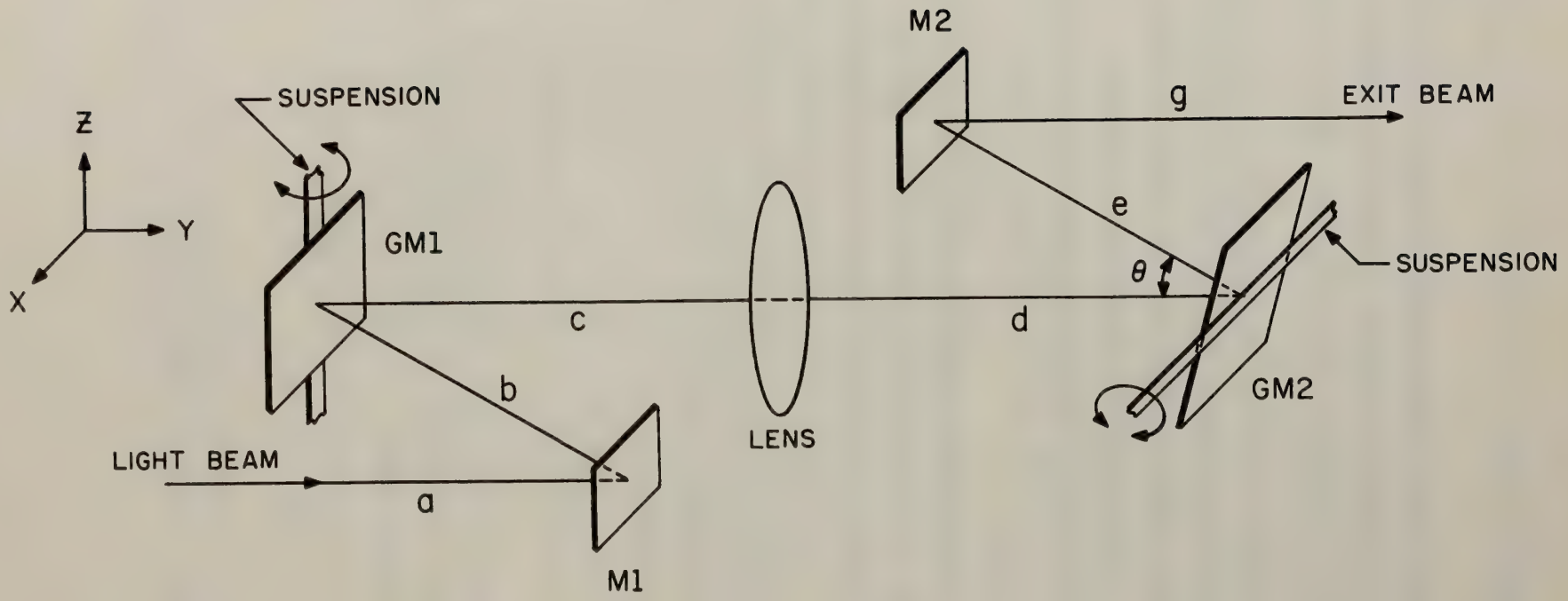

Figure 1. Simplified Diagram of Two-Dimensional Light-Deflectors

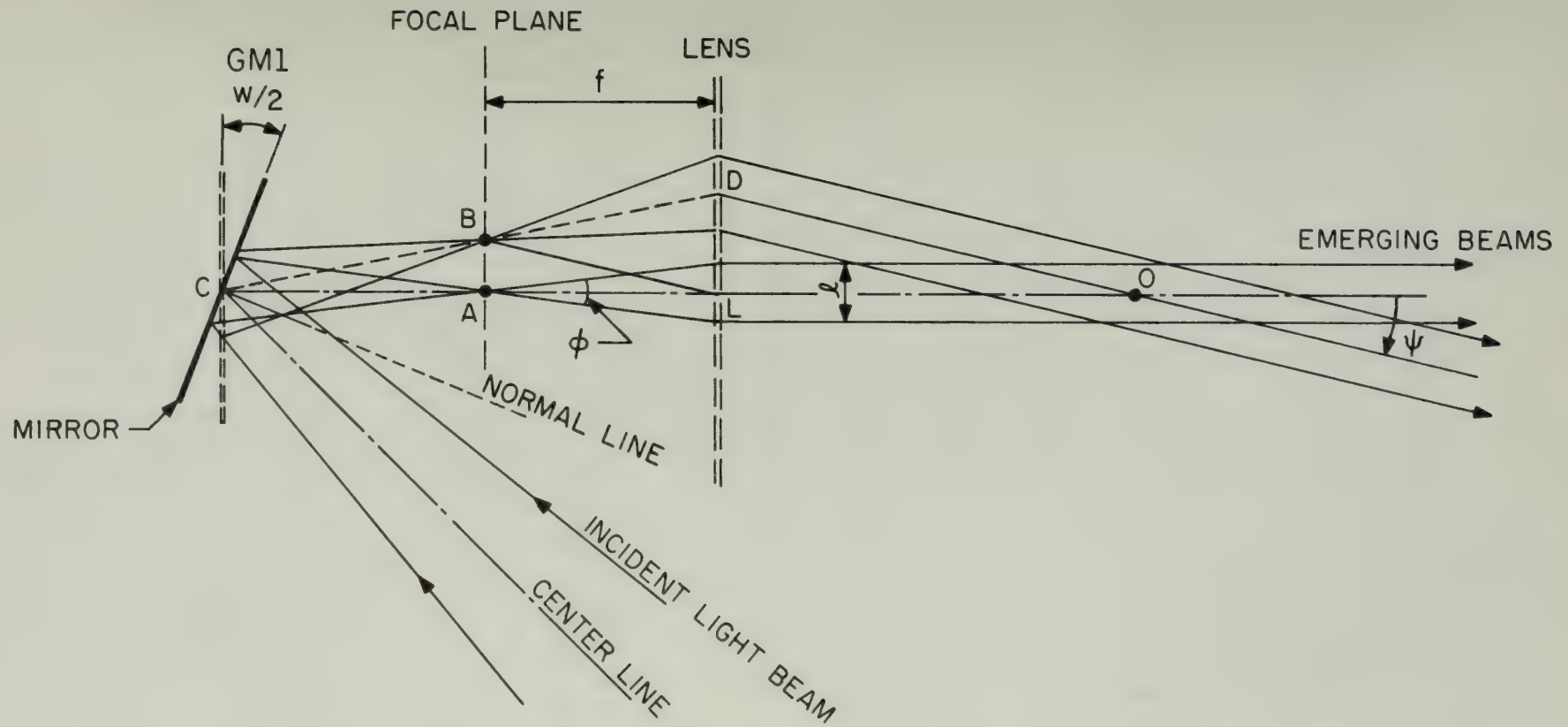

Figure 2. Shift in Beam Path Due to Mirror Rotation.

1.2.2 Disadvantages of this System

1.2.2.1 Dispersion of Light Beam

The main source of dispersion is found to be the shift in node point A out of the focal plane. This node point describes a circular path, centered at C with radius CA. For small angles of rotation of GM1, the shift BD, in Figure 3, is given by:

$$BD \simeq CA\ [\sec w - 1].$$

while the beam diameter in the focal plane is

$$km = CA\ [1 - \cos w][\tan\ (w + \frac{\phi}{2}) - \tan\ (w - \frac{\phi}{2})]$$

By definition, the dispersion thus becomes

$$\delta = \frac{km}{f} = \frac{CA}{f}\ [1 - \cos w][\tan\ (w + \frac{\phi}{2}) - \tan\ (w - \frac{\phi}{2})]$$

In practice, both w and ϕ are small, and δ is given approximately by

$$\delta = \frac{CA}{f} \cdot w \cdot \phi$$

For a given system the dispersion is thus directly proportional to ϕ, the latter angle being directly determined by the characteristics of the primary source.

Typical figures are as follows: For $2w = 0.03$ rad and $CA = f$ a dispersion angle of 0.1 degree requires a ϕ of less than 3.5 degrees.

1.2.2.2 Modulation of Beam Width

Shift in the optical path from C to O results in modulation of the beam width. From Figure 3:

$$\ell = \ell' \sec 2w \cdot \cos \psi$$

and

$$\ell' = 2[(CA + f) \sec w - CA]\ \tan \frac{\phi}{2}$$

$$\psi \simeq \frac{f}{AC}\ w$$

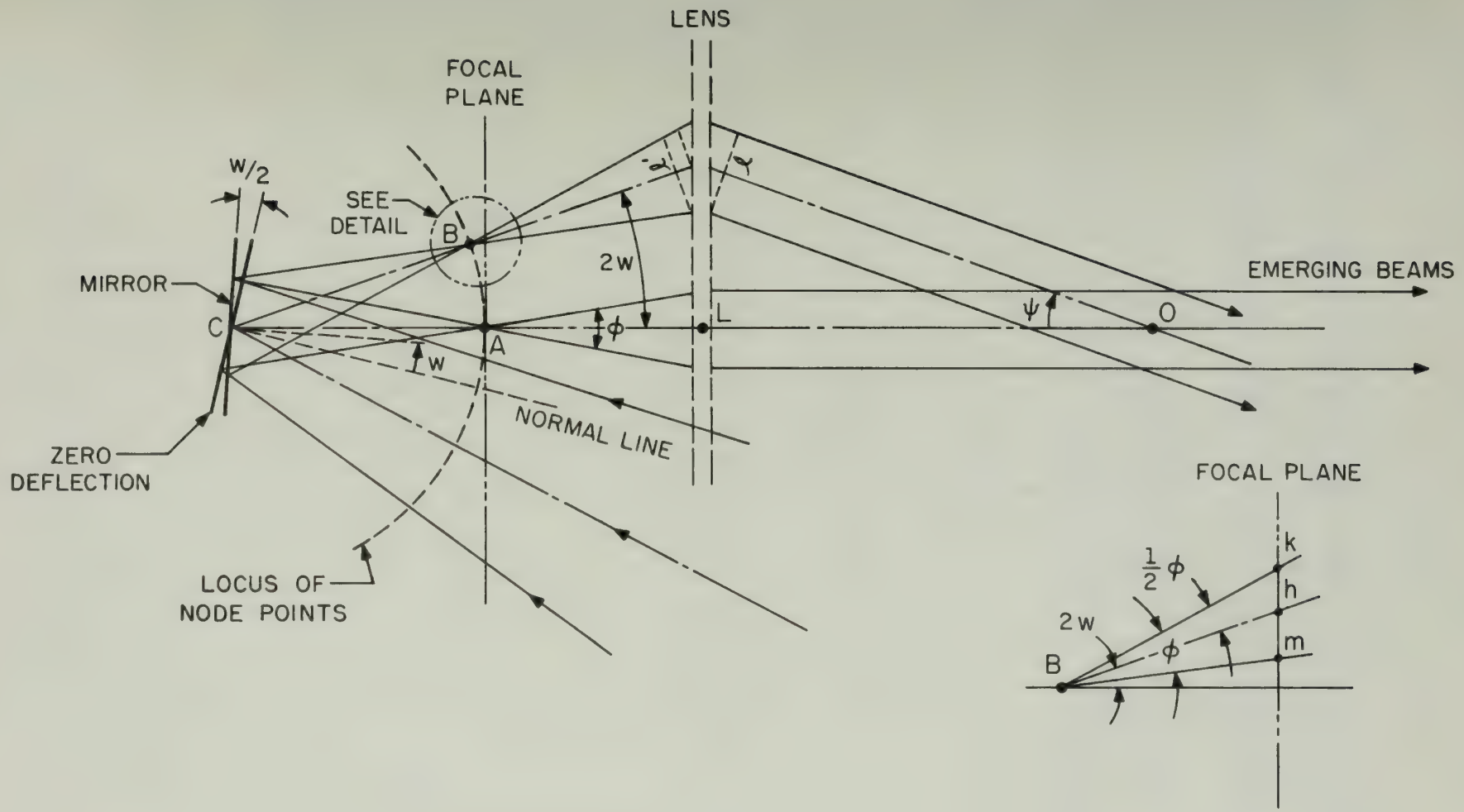

Figure 3. Dispersion in the Optical System.

so that

$$\ell = 2[(CA + f) \sec w - CA] \tan \frac{\phi}{2} \sec w . \cos \left(\frac{f}{CA} w\right)$$

When $CA \simeq f$, while rotational angles are small, there follows:

$$\ell \simeq \phi . f . [2 \sec w - 1].$$

Denoting the beam width, at zero deflection, as ℓ_0, where $\ell_0 = \phi . f$, it then follows that

$$\frac{\ell}{\ell_0} = 2 \sec w - 1$$

$$\simeq 1 + w^2$$

Beam width modulation is then seen to be a second order effect and, at the rotations envisaged, will most probably be negligible.

Dick Koo.

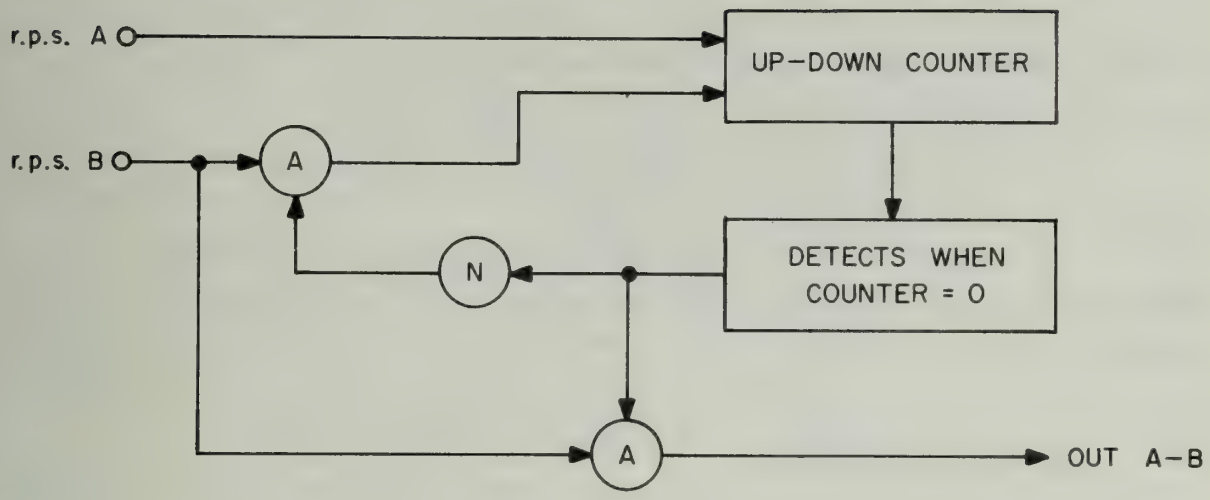

Figure 1. Direct Subtraction - Method 1.

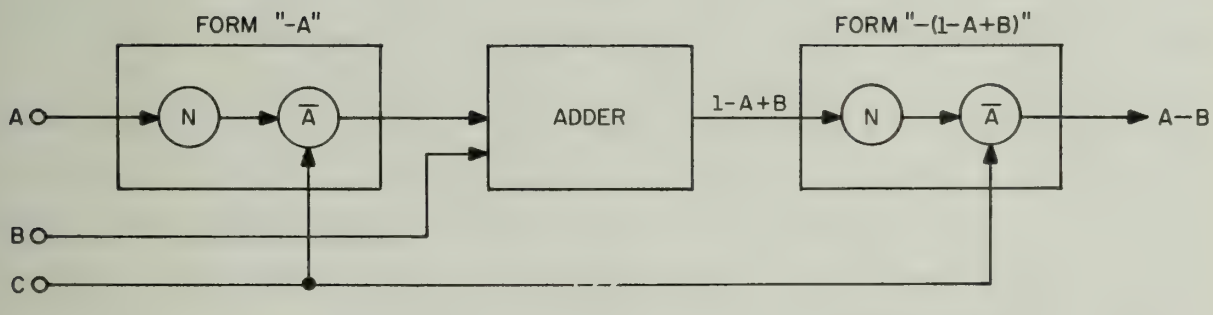

Figure 2. Subtraction by Complementation - Method 2.

1.3 RANDOM SEQUENCE CODING

1.3.1 General

Two schemes are proposed for subtraction, using the synchronous random sequence. One of these schemes has been analyzed sufficiently to indicate that predicted and experimental results agree.

Motivation for further exploring the possibilities of the synchronous random sequence system is presented.

A correction to the description of the first order compensated adder for a random sequence system, as described in the previous QTPR, is presented.

1.3.2 Subtraction: Method 1.

Two RPS's, A and B, are assumed to be present. A pulse is now deleted from A for each pulse occurring in B. If, in a certain defined interval, more pulses occur in A than in B, the difference is registered on a counter. Figure 1 shows how this is accomplished with the use of an up and down counter.

1.3.3 Subtraction: Method 2.

This scheme was conceived in an attempt at representing a negative number in complement, on a single wire system.

Let A be an RPS with a probability, a, of being a logical one "-A" is now set equal to 1-A, which logically, is $\bar{A}C$. C is the periodic sequence to which A is synchronized as described in the QTPR October-December, 1966. The sequence 1-A has a probability of being a logical one, equal to 1-a. Assume that it is desired to subtract RPS B (with probability "b" of being a logical one) from RPS A. Both 1-A and B are now fed into the adder (described in the October-December 1966 QTPR) giving an output of 1-A+B with probability of 1-a+b. If one forms -(1-A+B), there results:

$$\overline{(1-A+B)}.C = 1-(1-A+B) = A-B.$$

Schematically the operations are shown in Figure 2. Both schemes outlined hold promise of successful application and their realization is currently

being undertaken. Certain problems are apparent in both schemes, the most important being noted below.

First, the relative magnitudes of the two probabilities have to be known so that the smaller may always be subtracted from the larger. An averaging method (like R-C integration) may be used with each RPS and the outputs compared in a differential amplifier.

Secondly, in a one wire complementary system there is the problem of sign determination. This could be accomplished by comparing the average value of the RPS with a series of known average value of $\frac{1}{2}$. Also, a sign bit could at known times be superimposed on the RPS.

The simplest computing elements will, however, probably result from the use of a two wire system.

1.3.4 Erratum

An error has been found in the description of the first order compensated adder for the synchronous random sequence system.

The probability associated with the output of the first order compensated adder in the last quarterly report was given as $n_z/n = n_x/n + n_y/n - (n_x/n)^2(n_y/n)^2$. In this expression, the last term has been found to be incorrect.

Since a pulse which comes out of an AND gate is fed to the OR gate after shifting one clock cycle, this compensation is not valid if the subsequent cycle is occupied by a pulse of either one of the inputs or of both. The probability that the cycle subsequent to a coincidence is occupied by a pulse is $(n_x/n)(n_y/n)\left\{n_x/n + n_y/n - (n_x/n)(n_y/n)\right\}$. Therefore the correct expression for the probability associated with the first order compensated adder is

$$n_z/n = n_x/n + n_y/n - (n_x/n)(n_y/n)\left\{n_x/n + n_y/n - (n_x/n)(n_y/n)\right\}.$$

Compensation of higher order in this manner seems unattractive. However, there is another scheme of compensation which is being developed.

1.3.5 Theoretical Analysis of the First Order Subtracter by Direct Subtraction.

Let A and B denote the minuend and subtrahend random sequences with accompanying probabilities a and b, respectively. Then, $a \simeq$ (number of pulses of sequence A during the averaging time)/(number of the clock pulses during the averaging time), and so on.

As the result of subtraction, we wish to form a random sequence whose accompanying probability, c, is given by $c = a - b$, assuming $a \geq b$. In the subtracter by direct subtraction the resultant sequence, C, is formed from A by deleting pulses each of which corresponds to every pulse of B. As the first order approximation of this operation, the first order subtracter has the following functions:

(1) Those pulses of A and B which coincide with each other are deleted, and new sequences A' and B' which no longer have coincident pulses are obtained.

(2) If at least one pulse of B' appears between two pulses of A', then one pulse of A' is deleted. The sequence obtained is the output of the first order subtracter.

The above mentioned functions are illustrated in Figure 3. An arrowed-line indicates a pair of pulses for each deletion. (1) is accomplished with the use of an AND gate. For (2) we need a storage element to store one pulse (a special case of the up-down counter). If there are more than two pulses of B' between the pulses of A', only the first one is effective for subtraction, and the rest of them are discarded and thereby produce an error.

In the following theoretical calculation, each step of analysis does not correspond to that of the actual function of the subtracter.

In order to estimate the error of the first order subtracter, let us consider a general situation depicted in Figure 4. An element of time interval has n blanks following a pulse of A and has one pulse at the end, where $n = 0, 1, 2, \ldots$. If there is at least one pulse of B in this time interval, the pulse of A at the $(n+1)^{th}$ clock cycle is deleted. Therefore,

$$P\{\text{A pulse of A in a time interval of length } (n+1) \text{ cycles is deleted}\} \qquad (1)$$

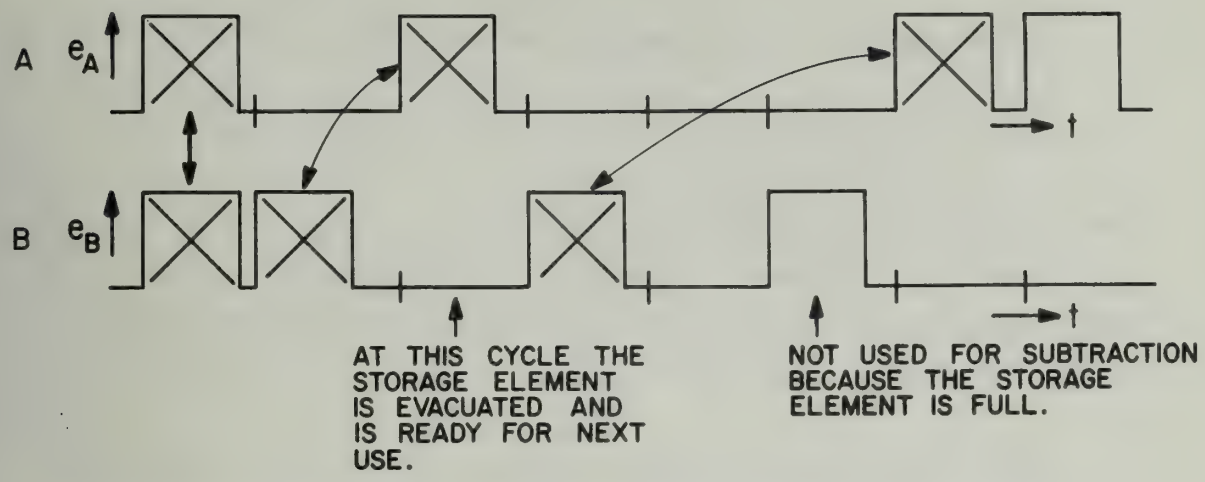

Figure 3. Illustration of Procedure of Subtraction in the First Order Subtracter by Direct Subtraction.

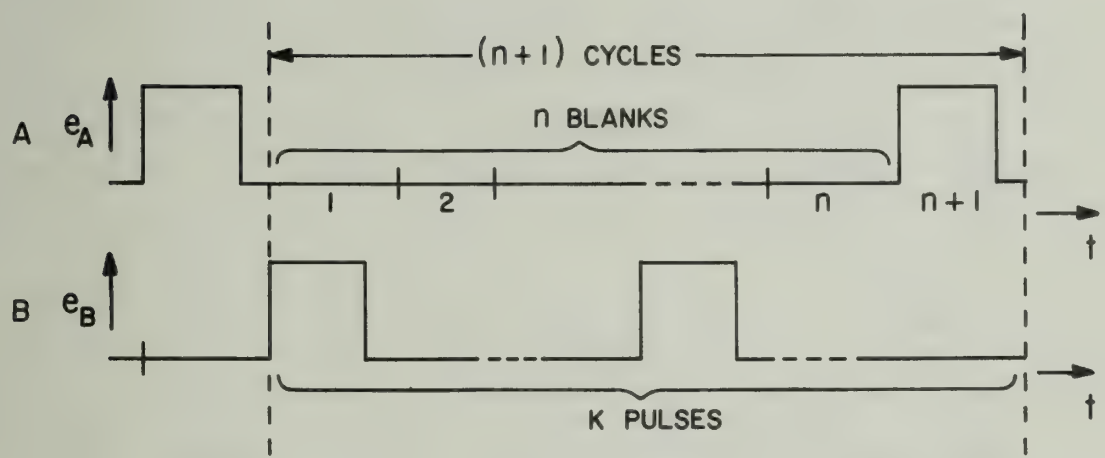

Figure 4. Correspondence of the Minuend and Subtrahend Sequences.

$$= P\{\text{A time interval of length } (n+1) \text{ cycles occurs in A and at least one pulse of B falls in this time interval}\} \quad (1)$$

$$= P\{\text{A time interval of length } (n+1) \text{ cycles occurs in A}\}$$

$$\times P\{\text{At least one pulse of B falls in this time interval}\}$$

provided that the sequences are independent.

Since the time scale is discrete in the synchronous random sequence, the distribution of pulses is described by the binomial distribution. Therefore,

$$P\{\text{A time interval of length } (n+1) \text{ cycles occurs in A}\} = (1-a)^n a \quad (2$$

$$P\{\text{At least one pulse of B falls in a time interval of length } (n+1) \text{ cycles}\}$$

$$= 1 - P\{\text{No pulse of B falls in a time interval of length } (n+1) \text{ cycles}\}$$

$$= 1-(1-b)^{n+1} \quad (3$$

$$P\{\text{A pulse of A is deleted} \mid \text{A pulse of A is present}\}$$

$$= \sum_{n=0}^{\infty} P\{\text{A pulse of A in a time interval of length } (n+1) \text{ cycles is deleted}\}$$

$$= \sum_{n=0}^{\infty} (1-a)^n a[1-(1-b)^{n+1}]$$

$$= \frac{b}{a+b-ab} \quad (4$$

This does not take account of all the cases, however. In order to see this let us consider the cases shown in Figure 5. If a pulse of B appears at the last cycle of the interval, it coincides with a pulse of A. Since the coincident pulses are deleted with a use of an AND gate, the storage element can store the first pulse in this interval and use it to delete a pulse of A in the subsequent interval if a pulse of B does not

precede that of A. In such a case two pulses of B in the first time interval are effective for subtraction. Therefore we need a correction due to this effect. There are three typical cases which are shown in Figure 5.

In the first case, which is shown in (i), the first pulse of B in the first interval is carried over to the second interval, and then it is used to delete a pulse of A in the second interval.

In (ii) the situation in the first interval is the same as that of (i), but the carried-over pulse does not produce a net effect because a pulse in the second interval is discarded owing to the carried-over pulse.

In (iii) it is not possible to decide whether or not the carried-over pulse produces a net effect unless the condition after the second coincidence is known.

Here we consider the conditions only up to the second coincidence and estimate the lower and upper bounds of the correction. If we consider only (i) we would have the lower bound because we discard (iii), some of which produce a net effect. On the other hand, if we take both (i) and (iii) for the correction, we would have the upper bound because not all the cases of (iii) are effective.

First let us find the probability that at least two pulses of B appear in the first interval and one of them coincides with a pulse of A. Figure 6 illustrates the cases of n = 1 and 2. The corresponding probabilities are also shown. From these it is not difficult to see that the probability for the general case is given by:

$$(1-a)^n a \sum_{r=2}^{n+1} \frac{r}{n+1} \binom{n+1}{r} b^r (1-b)^{n+1-r}$$

$$= (1-a)^n ab \sum_{r'=1}^{n} \binom{n}{r'} b^{r'} (1-b)^{n-r'}$$

$$= (1-a)^n ab \left[1 - (1-b)^n\right]$$

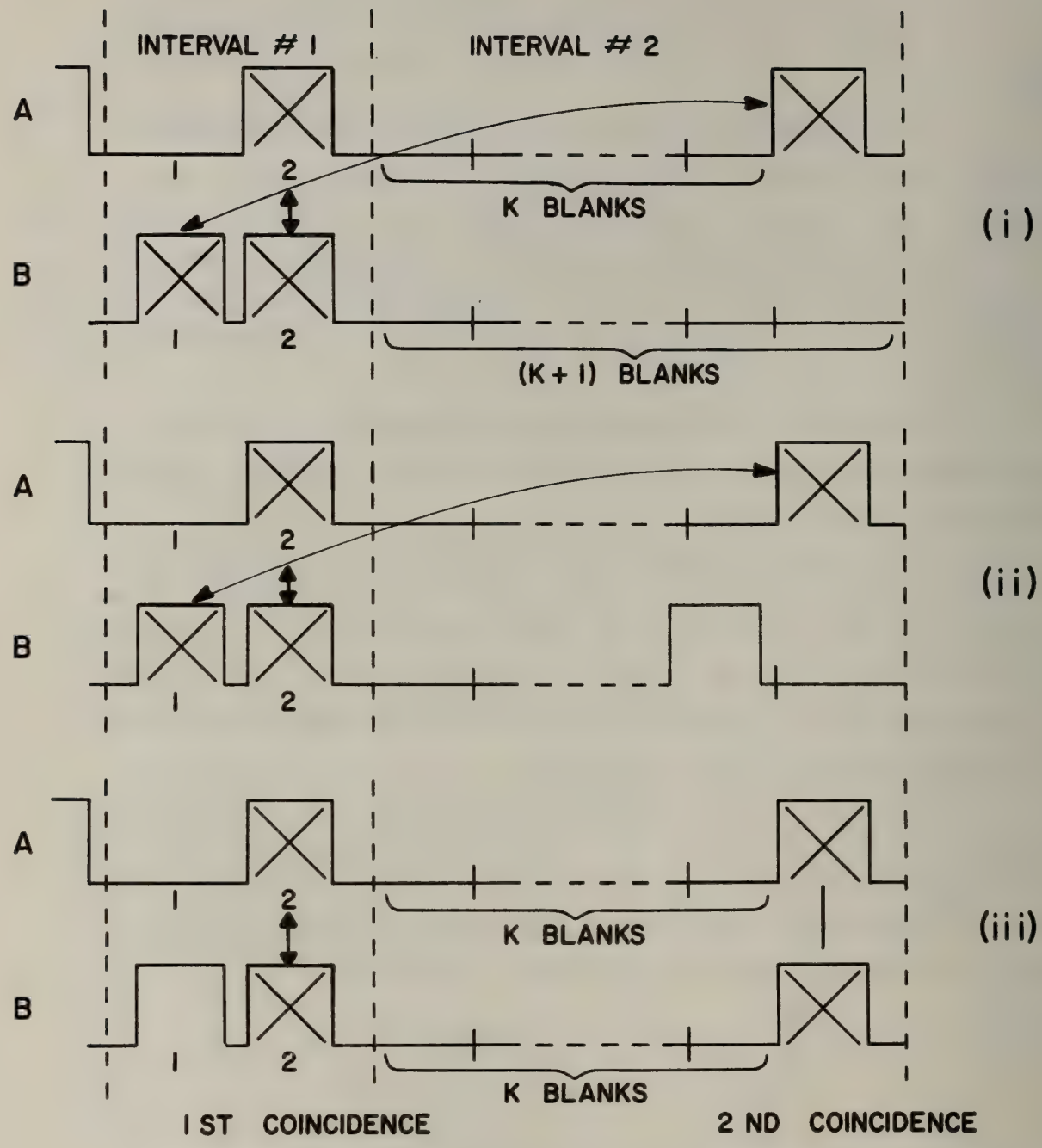

Figure 5. An Additional Deletion Occurs when Pulses of A and B Coincide.

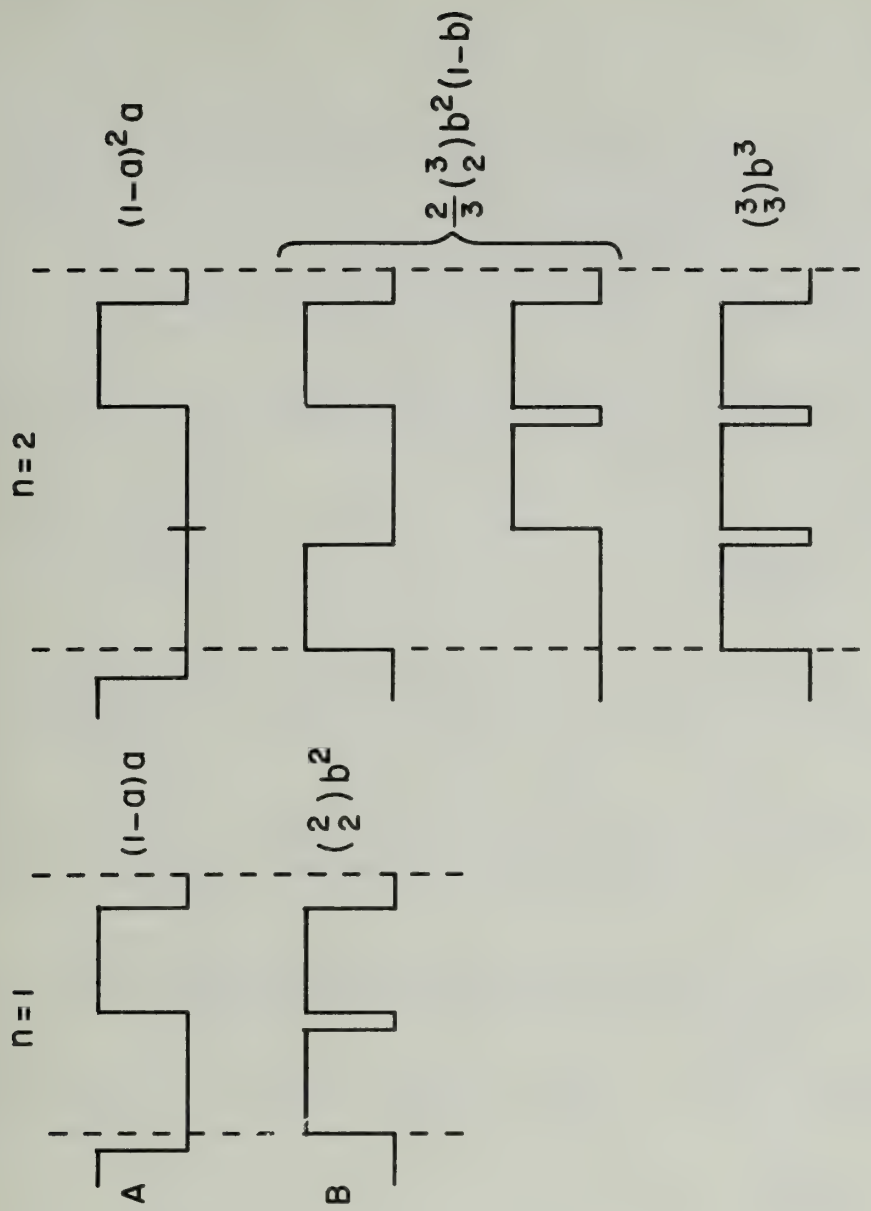

Figure 6. Illustration of the Cases Where an Additional Deletion Occurs.

Therefore,

$$P\{\text{At least two pulses appear in the first interval}\}$$

$$= \sum_{n=1}^{\infty} (1-a)^n ab[1-(1-b)^n]$$

$$= ab\left[\frac{1}{a} - \frac{1}{a+b-ab}\right]$$

$$= \frac{b^2(1-a)}{a+b-ab} \tag{5}$$

Next, let us consider the probability connected with the second interval. For the lower bound, referring to Figure 5 (i),

$$P\{\text{A pulse of A precedes a pulse of B in the second interval}\}$$

$$= \sum_{k=0}^{\infty} P\{\text{A has k blanks before a pulse appears and B has (k+1) blanks.}\}$$

$$= \sum_{k=0}^{\infty} (1-a)^k a(1-b)^{k+1}$$

$$= \frac{a(1-b)}{a+b-ab} \tag{6}$$

For the upper bound we take both (i) and (iii) and we have,

$$P\{\text{A pulse of B does not precede a pulse of A}\}$$

$$= \sum_{k=0}^{\infty} (1-a)^k a(1-b)^k$$

$$= \frac{a}{a+b-ab} \qquad (7)$$

Now the lower bound of the correction is, from (5) and (6),

$$P\{\text{At least two pulses of B appear in the first interval}\}$$

$$\times P\{\text{A pulse of A precedes a pulse of B in the second interval}\}$$

$$= \frac{b^2(1-a)}{a+b-ab} \cdot \frac{a(1-b)}{a+b-ab}$$

$$= \frac{ab^2(1-a)(1-b)}{(a+b-ab)^2} \qquad (8)$$

The upper bound of the correction is, from (5) and (7),

$$P\{\text{At least two pulses of B appear in the first interval}\}$$

$$\times P\{\text{A pulse of B does not precede a pulse of A in the second interval}\}$$

$$= \frac{b^2(1-a)}{a+b-ab} \cdot \frac{a}{a+b-ab}$$

$$= \frac{ab^2(1-a)}{(a+b)-ab)^2} \qquad (9)$$

Therefore the total probability that a pulse of A is deleted is the sum of (4) and (8) for the lower bound, and is the sum of (4) and (9) for the upper bound, i.e.,

$P(\ell)\{$A pulse of A is deleted, including correction $|$ A pulse of A is present$\}$

$$= \frac{b}{a+b-ab} + \frac{ab^2(1-a)(1-b)}{(a+b-ab)^2}$$

$$= \frac{b}{a+b-ab}\left[1 + \frac{ab(1-a)(1-b)}{a+b-ab}\right] \tag{10}$$

$P(u)\{$A pulse of A is deleted, including correction $|$ A pulse of A is present$\}$

$$= \frac{b}{a+b-ab} + \frac{ab^2(1-a)}{(a+b-ab)^2} = \frac{b}{a+b-ab}\left[1 + \frac{ab(1-a)}{a+b-ab}\right] \tag{11}$$

Since each pulse of A appears with probability a, the probability that a pulse of sequence A is deleted is given by,

$P(\ell)\{$A pulse of A is deleted$\}$

$=P(\ell)\{$A pulse of A is deleted $|$ A pulse of A is present$\} \cdot a$

$$= \frac{b}{1+b(1/a-1)}\left[1 + \frac{b(1-a)(1-b)}{1+b(1/a-1)}\right. = b(1\ell) \tag{12}$$

$P(u)\{$A pulse of A is deleted$\}$

$$= \frac{b}{1+b(1/a-1)}\left[1 + \frac{b(1-a)}{1+b(1/a-1)}\right] = b(1u) \tag{13}$$

Finally the probability accompanying the output sequence of the first order subtracter is

a	b	b(lu)/b in %	b(lℓ)/b in %
0.10	0.01	92.5	92.5
0.10	0.05	71.1	71.0
0.10	0.10	55.0	54.8
0.20	0.02	94.0	94.0
0.20	0.10	75.6	75.5
0.20	0.20	60.5	59.6
0.30	0.03	95.5	95.4
0.30	0.15	79.8	78.8
0.30	0.30	62.2	64.0
0.40	0.04	96.6	96.5
0.40	0.20	84.1	82.7
0.40	0.40	71.9	68.1
0.50	0.05	97.5	97.4
0.50	0.25	88.0	86.0
0.50	0.50	77.8	72.4
0.60	0.06	98.4	98.3
0.60	0.30	91.7	89.2
0.60	0.60	83.7	76.3

Table 1. Numerical Examples of the Accuracy of the First Order Subtracter by Direct Subtraction.

$$a - \frac{b}{1+b(1/a-1)} \left[1 + \frac{b(1-a)}{1+b(1/a-1)}\right]$$

$$= a-b \left[\frac{1}{1+b(1/a-1)} \left\{1 + \frac{b(1-a)}{1+b(1/a-1)}\right\}\right] \text{ as the lower bound} \quad (14)$$

$$= a-b(1u)$$

$$a-b\left[\frac{1}{1+b(1/a-1)} \left\{1 + \frac{b(1-a)(1-b)}{1+b(1/a-1)}\right\}\right] \text{ as the upper bound} \quad (15)$$

$$= a-b(1\ell)$$

Since we wish to have a-b as the probability accompanying the output, the coefficients of b in (14) and (15), which are less than unity, determine the error of the subtracter.

Numerical examples are shown in Table 1. If the ratio b/a is less than 0.1, i.e., the subtrahend is much smaller than the minuend, the first order subtracter gives quite a satisfactory result. As a and b increase the situation becomes better.

An experimental unit has been built and tested. The results agree with the theoretical values very well. The clock frequency is 1 MHz and a = 0.1 corresponds to the average frequency of 100 kHz, and so on. Since the higher subtracter is being developed, the actual structure of the unit will be presented in the next report in a unified form.

Chushin Afuso
John Esch

1.4 Electro-Luminescent Panel (Project No. 07)

1.4.1 Circuit Changes

The two-input AND-gates in the decoder, will be replaced by NAND gates. This is partly a matter of convenience as I.C. cards containing these gates are available in number, but it also has some practical advantages.

The original AND-gate arrangement was as shown in Figure 1(a) while the new arrangement is in Figure 1(b).

Each row of the switch matrix normally stays at -5 volts, unless the emitter follower moves it up to zero. The -5 volt level is maintained as shown in Figure 2. The "0" state input to the I.C. NAND-gate requires 1.6mA at any voltage between -4.6 and -5 volts, while for the "1" state, 40μA at between 0 and -2.0 volts is needed. Thus the extra supply, V, in Figure 2 is required. For V = 10 volts, R has to drop 5 volts for 1.6mA,

thus giving $R = \frac{5}{1.6} \times 10^{+3} = 3.12$ k Ω.

The need for the separate supply may be obviated by the arrangement of Figure 3. The rows of the switch matrix are now kept at zero and upon application of a signal will be moved down to -5 volts. The I.C. NAND is such that if its input is floating, it is a "1" input, thus the switching matrix rows may be left floating.

A limitation on the allowed voltage drop across a switching matrix diode is however introduced. The maximum input value at which the I.C. NAND will still be "0" is -4.2 volts, while the switching voltage lies between -4.6 and -5.0 volts as stated. At the rated I.C. "0" current of 1.6 mA, the diode drop should thus be less than 0.4 volts.

A suggested driving circuit with input AND is shown in Figure 4.

A detailed study of available literature on the electroluminescent phenomenon has been made. A report, describing current views on the mechanism of electroluminescence has been written and is to be issued soon.

Tak Katoh

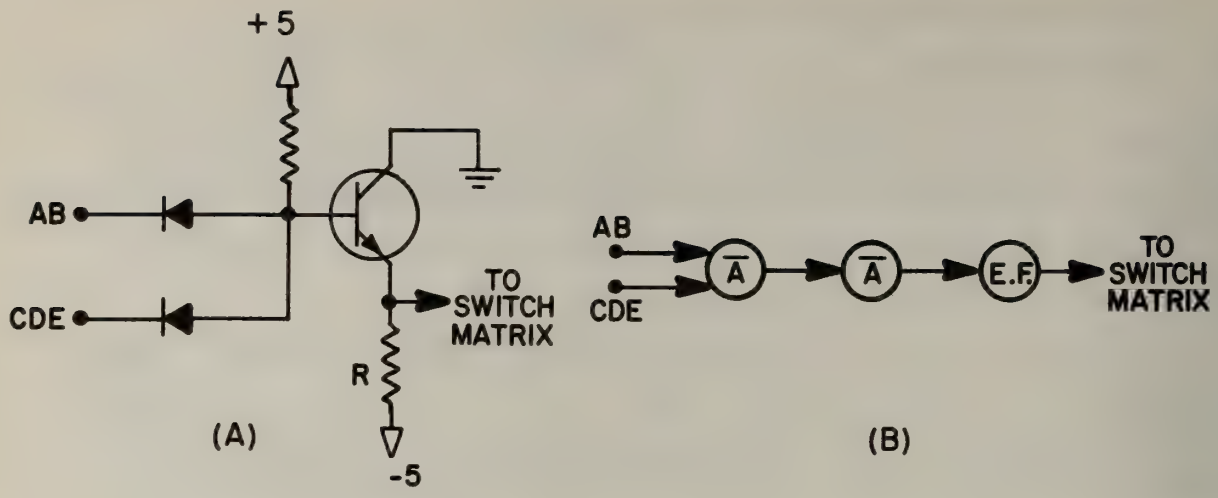

Figure 1. Replacement of AND- by Two NAND-Circuits.

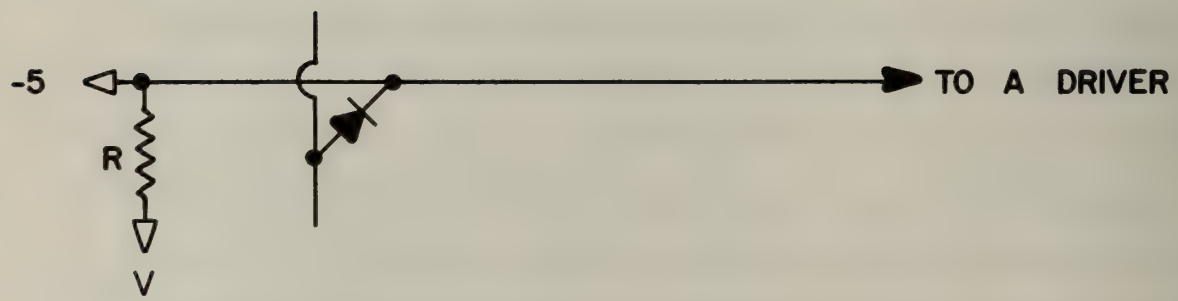

Figure 2. Supply on Switch Matrix Rows.

Figure 3. Alternative Arrangement with NAND-Gates.

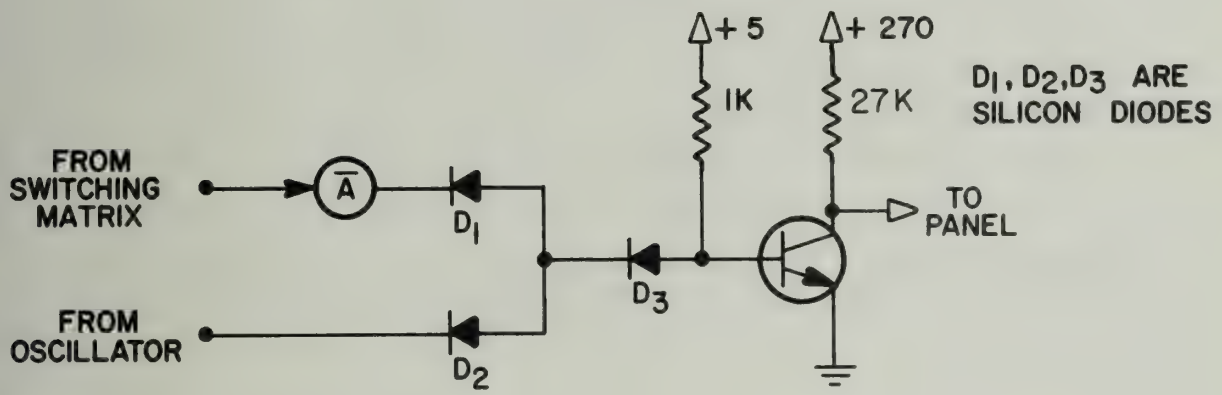

Figure 4. Suggested Driver Circuit.

1.5 GEOMATRIX (Project No.08)

1.5.1 Geomatrix I:

The basic design of the Geomatrix system for autonomously displaying straight lines has been completed and construction has reached an advanced stage. This system, tentatively designated Geomatrix I, has been adequately described in the previous Quarterly Reports, notably those covering April-December, 1966.

An extension of the Geomatrix principle, aiming at removing the restriction to linear segments is currently under investigation. This system is designated Geomatrix II.

1.5.2 Geomatrix II - Introduction

The Geomatrix II extension of Geomatrix I is a proposed electronic system for generating and displaying all curves which are solutions of Laplace's equation. Hybrid digital-analog circuits are envisaged for the display of at least all conic sections and probably other curves, too.

Whereas previous systems in this field have depended upon electronic generation of an equation to fit the desired display, this new system employs equipotential contours, analogous to the linear array of equipotential points in Geomatrix I.

The basic idea is to construct a raster of resistors and to associate with each raster point an autonomous element that determines if that element lies on the desired geometric curve. The success of this system depends ultimately on whether the autonomous elements can be made inexpensively.

1.5.3 Practical Geomatrix II Configuration

In the resistive grid the potential distribution which satisfies Laplace's equation is governed by the imposed boundary conditions.

Sensing elements connected to each one of the node points in the resistive grid will provide a means of selecting any one of the equipotential lines and displaying its shape on a matrix of light sources. Each sensing element will be required to determine if the particular node potential is equal to a preset reference voltage, and if so, to light a corresponding point in the lamp matrix. Any equipotential contour on the grid can thus be selected by variations of the reference voltage.

Currently, three variations of the above system are being considered. Cost of autonomous elements will probably determine the final choice of system to be used.

1.5.4 Geomatrix II A

The boundary conditions on the grid are set by DC voltages. A detector circuit similar to that of Geomatrix I is used at each node, lighting a lamp if node and reference voltage correspond.

This circuit has been described in the January-March 1966 QTPR. It would correspond to having E_1, E_2, and E_R in Figure 1 below being DC voltages.

1.5.5 Geomatrix II B

The boundary conditions on the grid are supplied by sinusoidal voltages with a reference voltage of the same frequency but 180° out of phase. The sensing element is now set to react to equal amplitudes of node and reference voltages. In Figure 1 voltages are of the form

$$E_1 = A \sin\omega t$$

$$E_2 = B \sin\omega t$$

$$E_R = -C \sin\omega t$$

The proposed sensing circuit is as shown in Figure 2. The two resistors R_1 form a summing node at S, giving

$$V_s = k(A-C) \sin\omega t$$

When $A = C$, $V_s = 0$ and T_1 will be off, allowing T_2 to turn the lamp L, on. When $A \neq C$, $V_s = M \sin\omega t$ $(M>0)$, and T_1 will be on during the positive half of $\sin\omega t$. The base of T_2 will then be low enough to keep T_2, and the lamp, off. C ensures that T_2 remains off during the negative half of $\sin\omega t$.

High sensitivity to voltage difference between E_1 and E_2 requires low current consumption by the sensing element, which indicates a sizeable R_2. This, however, decreases the gain of T_1.

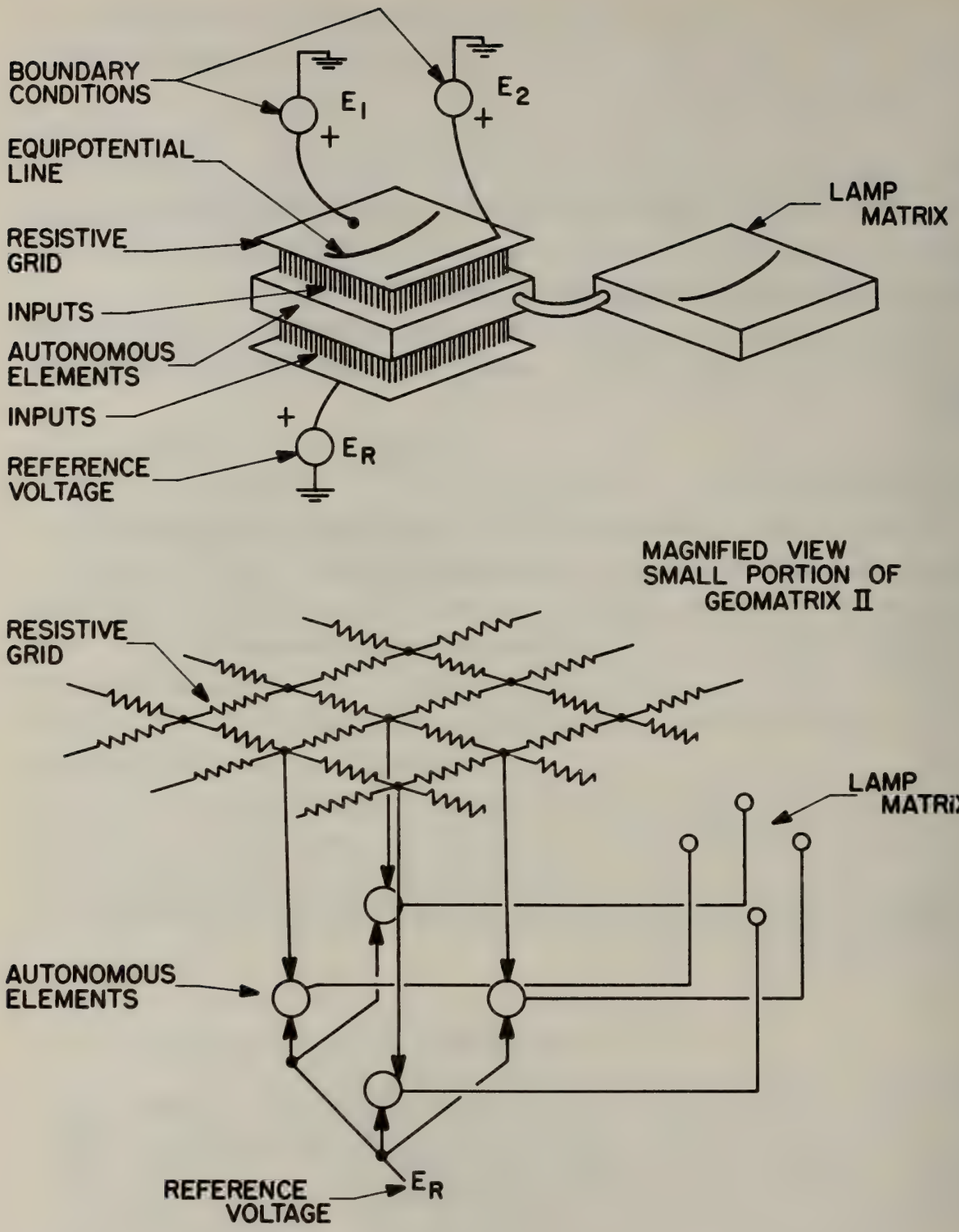

Figure 1. Schematic Diagram of GEOMATRIX II.

The ratio of V_C to (E_1-E_2) is given by:

$$\frac{V_C}{E_1-E_2} = \frac{\alpha(1+\beta)R_3}{R_1+2(1+\beta)R_2} < \frac{(1+\beta)R_3}{R_1}$$

The input impedance at, say, E_1 (with $E_2 = 0$) is given by

$$R_{IN} = R_1 + \frac{(1+\beta)R_1R_2}{R_1+(1+\beta)R_2} < 2R_1$$

Optimization of the above circuit is currently being investigated.

William G. Steiner

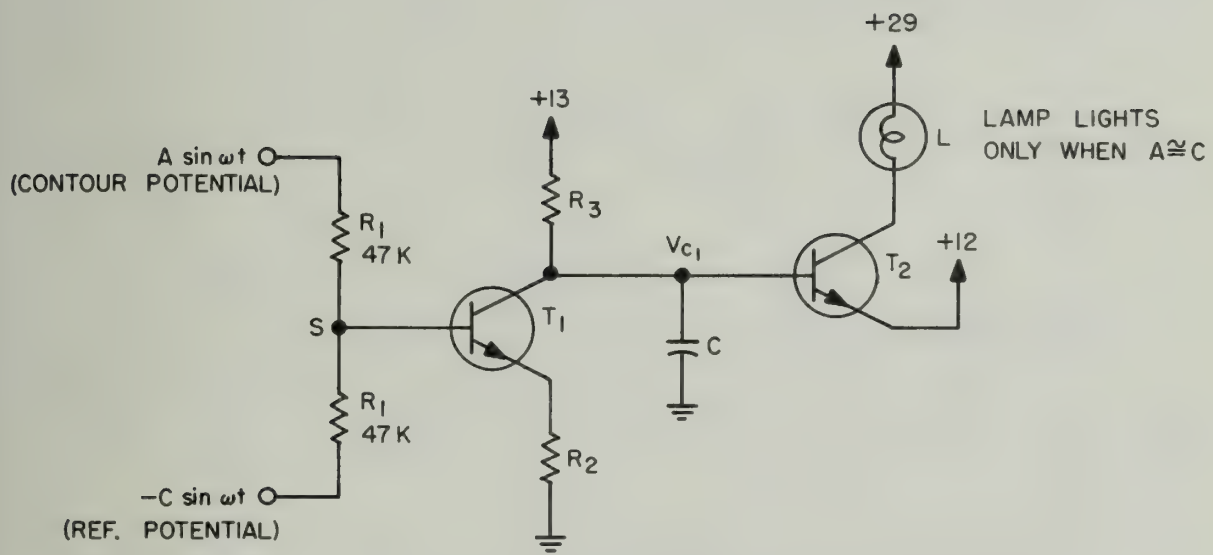

Figure 2. Sensing Circuit For GEOMATRIX II B.

1.6 Analog Computation Using Field Effect Transistors (Project No. 09)

1.6.1 Introduction

This project aims at performing simple computations like multiplications and divisions by using known variations in FET parameters. In particular, it is proposed that the linear region of the drain voltage-drain current family of curves be employed-the specific region is indicated in Figure 1.

Assuming abrupt PN-junctions in the FET, simple calculation of depletion layer widths as functions of gate voltages, yields Equation 1 as as expression for the channel conductance, from drain to source:

$$G_{DS} = G_O \left[1-\left(\frac{V_G}{V_D}\right)^{\frac{1}{2}} \right] \qquad (1)$$

where G_O is the channel conductance at zero gate voltage, V_G is the voltage between gate and source, and V_D is the value of V_G for which $G_{DS} \rightarrow 0$.

In practice, G_{DS} is found to deviate from the relation of Equation 1 and has been shown by Shipley [1] to be given by the linear relation of Equation 2, to within a few percent. [2,3]

$$G_{DS} \simeq G_O \left(1- \frac{V_G}{V_D}\right) \qquad (2)$$

1.6.2 Experimental Results

D.C. measurements at room temperature on a TI-2N3331 Si-F channel FET at values of $V_G < 0.7$ volts, indicate that Equation 2 is an acceptable approximation for this transistor.

1.6.3 Simple Computation - Multiplication

Channel conductance modulation by the gate voltage provides a means of retaining an output voltage containing a product term involving both the gate and the drain voltage.

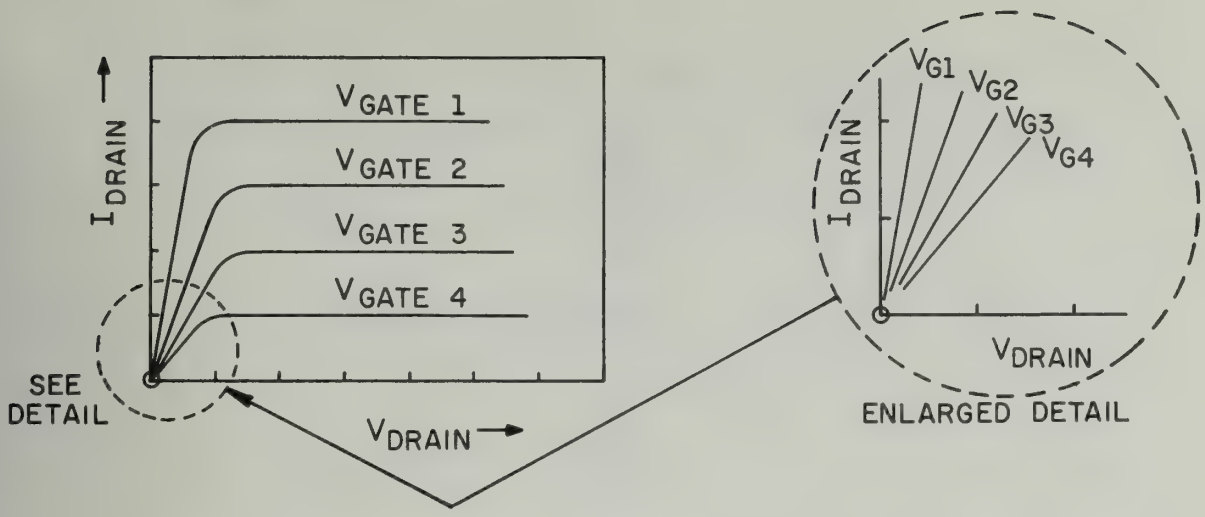

Figure 1. Linear Relationship in F.E.T. Characteristic Curves.

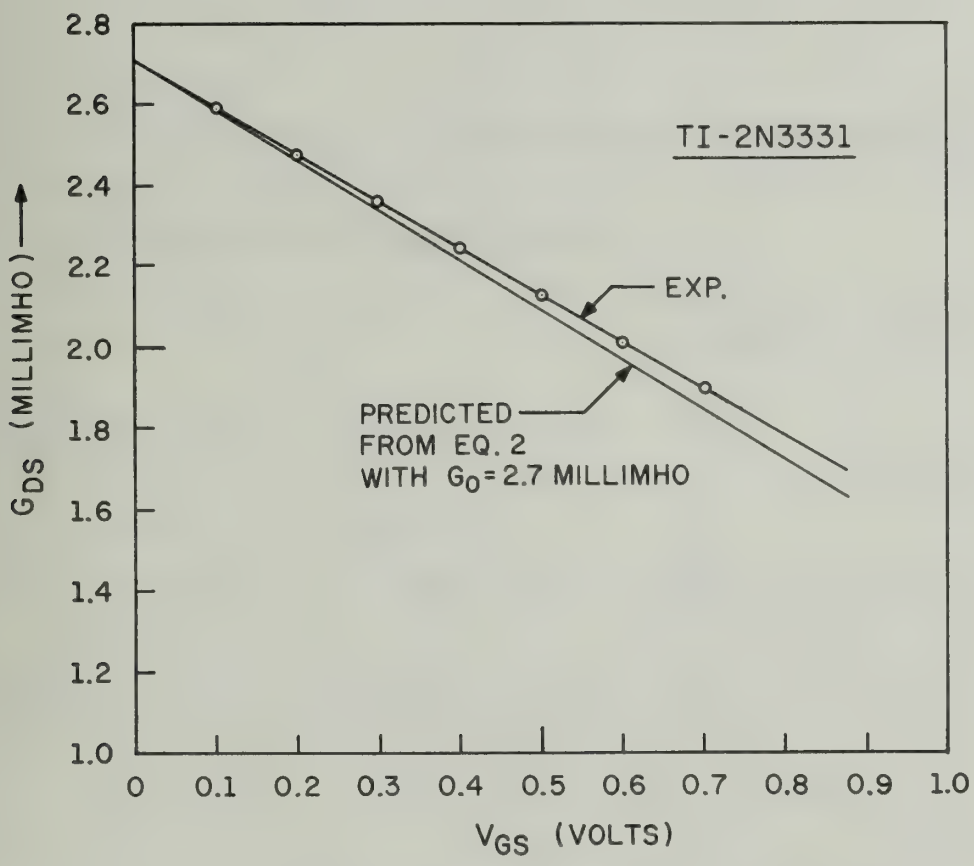

Figure 2. Experimental Plot of Channel Conductance vs. Gate Voltage.

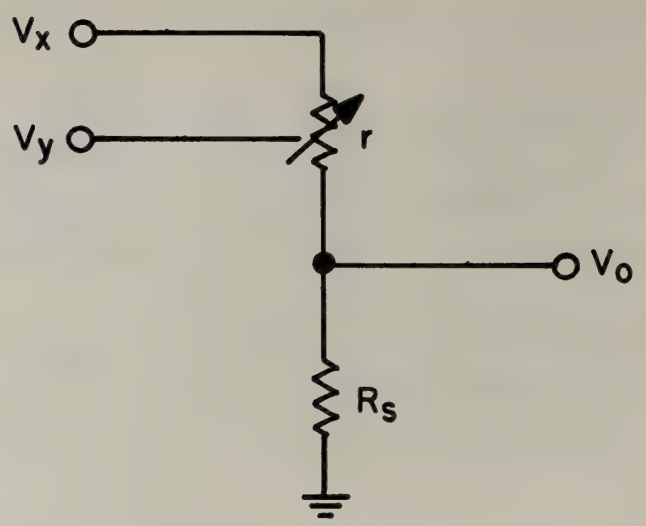

Figure 3. Schematic Diagram of Circuit for Multiplication.

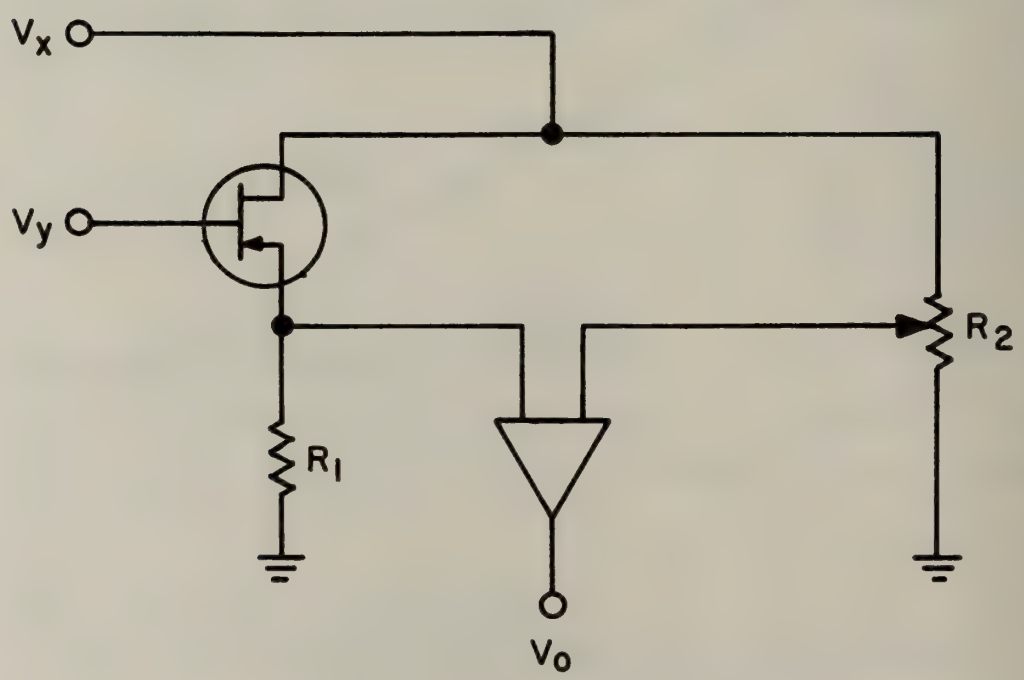

Figure 4. Proposed Circuit for Multiplication.

The proposed circuit is as in Figure 3. Representing the FET as a variable resistance of average value r, the voltage V_0 is given by

$$V_0 = \frac{R_S}{r+R_S} V_x$$

where V_x is a variable supply voltage and R_S is a fixed series resistance. By making $R_S \gg r$, and using Equation 2, there follows:

$$V_0 = K_1 V_x - K_2(V_x V_y) \qquad (3)$$

with $K_1 = R_1 G_0$

$$K_2 = \frac{R_1 G_0}{V_D}$$

For practical results the first term of Equation 3 has to be eliminated by subtracting this voltage from the output, leaving only K_2 as a scaling factor.

Due to the low operating voltage range, it is proposed that a difference amplifier be employed as in Figure 4.

Howard Schweitzer

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(1) Shipley, Sr. M., "Analog Switching Circuits Using Field Effect Devices", Electronics, December 28, 1964.

(2) Todd, C. D., "The FET as a Voltage Variable Resistor", Dickson Electronics Corporation Application Note, Vol. I, No. 4, September, 1965.

(3) Highleyman and Jacob, "An Analog Multiplier using Two FET's", IRE Transactions on Communication Systems, September, 1962.

(Supported in part by the Atomic Energy Commission under Contract No. AT(11-1)-1469).

Summary

David Casasent and Douglas Sand describe the layout of the equipment to be used in the OLFT System, treat the problem of correcting a laser beam for uniform intensity, and describe some preliminary experiements. The use of a video disc recorder to detect the Delta Information between adjacent video scans is discussed by David Rollenhagen. In the Functional Encoding project Edward Carr, Peter Oberbeck, and Arthur Simons have extended their previous proposals to the design of transmitting and receiving units. Finally, William Kubitz analyzes several potential coloring techniques for the Tricolor Cartograph and selects one that seems attractive.

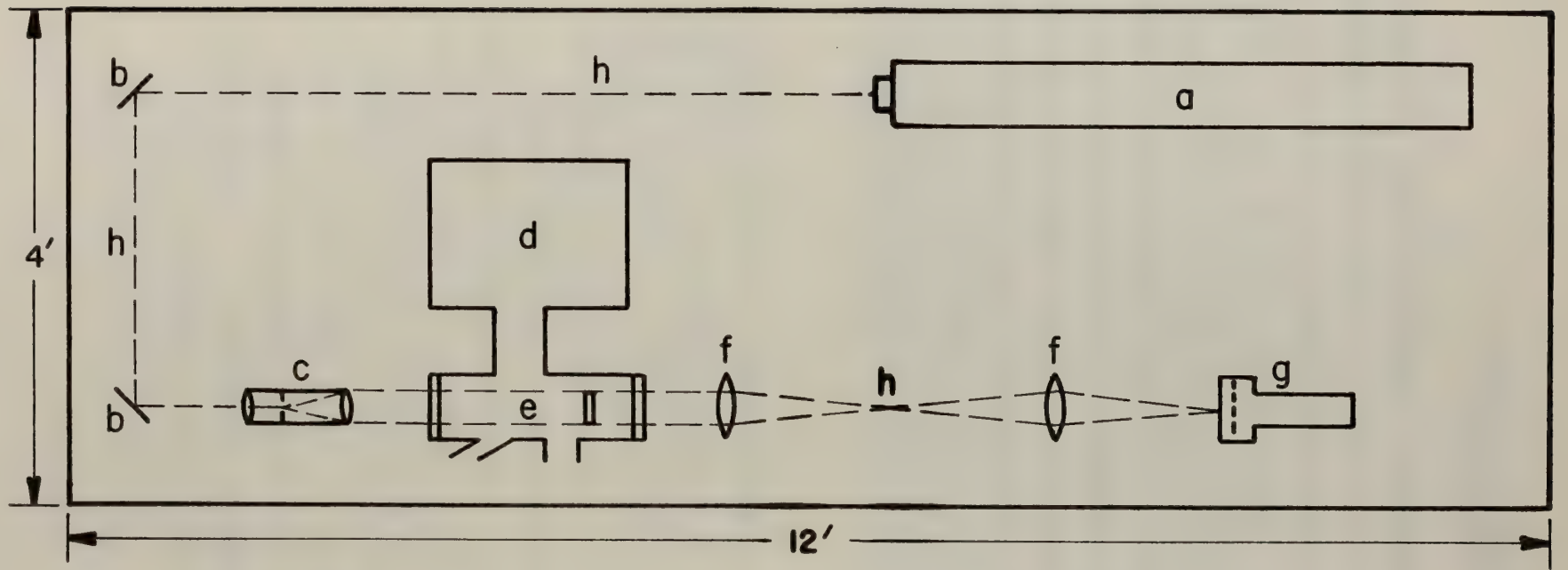
2.1 On-Line Fourier Transform (OLFT) System (Project No. 12)

2.1.1 General

The Fourier Transform system which has been presented previously in block form consists of four main sections: the laser and its accessories, the KDP chamber with its electronics and vacuum system, the Fourier Transform optics, and the pickup tube. The light output from the laser is a uniphase, unimode beam of 2 mm diameter and 50 mw power. The electron write gun in the chamber is capable of resolving a 500 line pattern of a television picture on-line with a 1 mil spot size. The optics must be highly corrected and capable of forming the Fourier Transform of the pattern displayed on the crystal modulator target in the solid state light valve. This Fourier Transform is imaged on the target of a pickup tube which is then scanned or masked in various ways, such as annular or pie-shaped sections. With such specifications and for the picture quality desired, great care must be taken to avoid building, air or noise vibrations and wavefront distortions.

2.1.2 Optical Table

The system has an overall optical length in excess of 15 feet. An optical path of this length requires precise alignment of optical components (particularly for stable, real-time operation) necessitating care in the choice of a table to support the system. Vibrations may become a severe problem. The conventional technique of placing a large piece of granite on vibro-isolators is impractical due to the physical size required, the cost of such a table, the floor-loading problem, and other difficulties. Instead, a less orthodox design will be used. The table design chosen consists of a well-braced open framework constructed in module sections for ease of modification. The table top is a sandwich arrangement. On top of the framework is a high-density felt pad; over this is placed a piece of plywood, then another felt pad and finally another piece of plywood with a masonite top bonded to it. These four pieces are glued together and the lower piece of plywood is bolted through the lower piece of felt to the table framework, allowing the top piece of plywood and its felt pad cushion to be isolated from the framework and yet still be rigidly supported.



a. LASER
b. MIRROR
c. BEAM EXPANDER
d. VACUUM SYSTEM
e. CHAMBER
f. FOURIER TRANSFORM LENSES
g. PICKUP TUBE
h. LIGHT PATH

Figure 1. Table Layout of OLFT System.

Each table leg has a baseplate which rests in a dish of sand under which is another felt pad. The felt damps most vibrations above 10-15 Hz and the sand further damps these, as well as lower frequency vibrations, and also serves as a leveling aid.

The framework is made of aluminum to minimize any stray magnetic fields which might interfere with the focusing and deflection of the electron beam. The table top is nearly 4 inches thick and 12' x 4' in area. The light path must bend around one end of the table, reflected by two optically flat mirrors at one end. This system is more compact than an in-line configuration and the extra width and shorter length form a more sturdy structure with fewer strains and longitudinal vibrations than are present in a long thin system. The placement of the apparatus on the table top is shown in Figure 1.

2.1.3 Uniform Distribution Wavefronts

In coherent optical data processing, the (complex) transmission function describing the pattern is multiplied by the (complex) function describing the incoming wavefront. In the Fourier Transform plane this results in a convolution of the Fourier transform of the pattern with that of the incoming wavefront (assuming diffraction limited optics). Ideally the incoming wavefront should be uniform in both phase and amplitude over the finite extent of the pattern, and zero elsewhere. The resulting Fourier Transform would then be that of the pattern itself. If the incoming wavefront deviates from a uniform distribution, the transmitted light pattern is a distortion of the transparency and the resulting Fourier Transform is correspondingly distorted.

2.1.4 Laser Wavefront

For the OIFT system the collimated output intensity of the laser is described by a Gaussian distribution - anything but uniform. The Fourier transform of a Gaussian function is again Gaussian, giving an unacceptable distortion to the transform of the pattern.

The objective, then, is to obtain the effect of a uniform distribution for the incoming wavefront. One possible solution is to bias the transparency pattern itself with an apprpriate correction function.

However, this would require a complicated system of electronics to attain proper correction, especially since this approach requires amplitude alteration which with the KDP modulator can only be done by a very non-linear modulation function. Another approach is to correct the wavefront before it passes through the transparency pattern. This has the obvious advantage that the problem of non-uniformity of wavefront is isolated from the major problem of producing the transparency pattern. A discussion of this approach follows, preceded by a brief description of the laser wavefront.

The optical resonator of the laser operates in the TEM_{00} node, resulting in a uniphase output having a Gaussian intensity distribution[1]:

$$I_L(r) = \frac{P_0}{2\pi a^2} \exp\left(-\frac{r^2}{2a^2}\right)$$

where r is the radial distance from the center of the wavefront, P_0 is the total output power (nominally 50 milliwatts) and a the "standard deviation" of the distribution (nominally, a = 0.5 mm, increased by collimation to about 1.25 cm). Note that $r = a\sqrt{2}$ describes the 1/e radius of the intensity.

2.1.5 Correction for Uniformity

Several techniques have been advanced to convert the Gaussian wavefront into a uniform wavefront. Some of these are discussed in reference 2, and are briefly summarized here:

1) Sum of Laser Modes. The laser resonator is allowed to resonate in several modes, the sum of which might approximate uniform intensity. This is difficult to accomplish in practice, and impossible for the OLFT laser, which is designed for single mode output only.

2) Use of only the central region of the beam. Here the beam is simply truncated to some radius b, using only the reasonably flat portion of the Gaussian. The net power W(b) resulting from such a truncation is:

$$W(b) = \int_0^b \int_0^{2\pi} I_L(r) r dr d\phi$$

$$= P_0 \left[1 - \exp\left(-b^2/2a^2\right)\right]$$

The intensity $I_L(b)$ at the edge is

$$W(b) = P_0[1-(I(b)/I_0)]$$

For a 10% variation of intensity over the truncated wavefront, $I(b)/I_0 = 0.9$ and $W(b) = 0.1\ P_0$, a completely unacceptable power loss for even this minor correction in nomuniformity.

3) Redistribution by Aspheric Optical Elements. This approach---fully described by Kreuzer in Reference 2---uses two active optical surfaces. The first spreads light from the center outward and the second corrects for uniform intensity and phase. The advantage of this approach is that only truncated power is lost. The disadvantages are that the surfaces must be aspheric (more severely aspheric for less truncation) and that the analysis assumes that geometrical optics apply. This approach will not be pursued further because the cost of custom aspheric surfaces offsets any slight gain in power.

4) Apodization, i.e., selective attenuation of the wavefront by using a filter with nonuniform transmission over its area. In this case the apodization filter is to attenuate more near the center of the wavefront than near the edge. There are several methods which produce usable filters, some of which can produce very uniform wavefronts. All filters of this kind have a maximum net power transmission of about 1/3, but their simplicity and flexibility make them very attractive. A description of the "ideal" apodization filter is given below, followed by a brief discussion of some possible realizations and a detailed discussion of the most promising version.

The ideal filter would flatten the intensity out to some radius r_0 and truncate the rest. If $T_i(r)$ describes the (intensity or power) transmission of this ideal filter, then

$$T_i(r) = \exp\ [(r^2-r_0^2)/2a^2],\ r \leq r_0$$

$$T_i(r) = 0,\ r > r_0$$

Obviously the filter is removing power from the original wavefront, so we would like to maximize the filtered power (with respect to the only unconstrained variable r_0). The net power $W(r_0)$ of a wavefront truncated to r_0 is simply

$$W(r_0) = \int_0^{r_0} \int_0^{2\pi} I(r, \phi)\, r\,dr\,d\phi$$

In the case of uniform intensity:

$$W(r_0) = (\pi r_0^2) I_0 = (\pi r_0^2) I_L(r_0).$$

Maximizing $W(r_0)$ with respect to r_0 yields

$$r_0 = a\sqrt{2} \text{ and } W_{max} = P/e$$

That is, the ideal apodization filter passes a maximum of 1/e of the input power (about 37%). This is a large but not severe power loss. (Note that $r_0 = a\sqrt{2}$ is also the 1/e radius of the Gaussian distribution.

2.1.6 Realizable Apodization Filters

An apodization filter is almost always constructed with some absorbing medium to achieve the desired attenuation. All homogeneous absorbing media follow Lambert's law,[3] which, for light propagating in the z- direction, gives the intensity as

$$I(z) = I_0 \exp(-Kz)$$

The constant K is the absorption coefficient. Note that this does not include losses due to reflection at interfaces (must be minimized by anti-reflection coatings).

It is convenient to define an absorption (or optical) density D as

$$D(X, Y, Z) = Kz$$

Now for the ideal filter:

$$D_i(z) = Kz = (r_0^2 - r^2)/2a^2$$

If we ignore the general case of K = K(X, Y, Z) we can distinguish two useful cases: either we have a constant thickness medium for which K = K(X, Y) or we vary the thickness Z = Z(X, Y) and let the absorption coefficient K remain constant. The first case describes an exposed and developed photographic plate, where the thickness of the emulsion is constant and the density of absorbing particles varies, or a constant thickness photochromic film. The second case describes a layer of absorbing medium with varying thickness.

The constant thickness films are best represented by photographic plates. That is, a photographic plate is exposed directly to the laser beam. When developed the plate is darker where the beam is more intense, and thus approximates the ideal filter. A Spectra Physics representative described briefly some of their attempts in this direction, claiming uniformity to within about 5%. However, a good photographic filter requires a trial and error procedure. Further, the physical thickness of the emulsion varies (as does the optical flatness of the photographic plate) introducing difficulties in maintaining a uniform phase front. One further point is that the absorbing medium on a photographic plate consists of particles of silver. The grain of the film must be fine to produce good uniformity but the fine particles then cause considerable scattering and introduce a high-frequency content to the resulting pattern, reducing the power content of the pattern-bandwidth in the Fourier Transform plane.

The difficulties associated with the photographic approach make it important to consider the alternative method---using a constant density with varying thickness. One possibility is to use vacuum deposition to achieve the proper thickness: For example, sputtering from a point source to a nearby flat plate. This is difficult, expensive, and also has phase problems. Another method is to use a gelatin mask cast in a shallow spherical cavity. This filter is fully described in Reference 4, which suggests the filter be used to correct for $\cos^3$ and $\cos^4$ intensity variations. The spherical gelatin filter seems most attractive and is discussed in detail below.

2.1.7 Spherical Gelatin Filter-Constructions

The spherical gelatin filter is constructed as follows (See Figure 2): An optical flat is selected and into one surface is ground a spherical cavity of spherical radius R and circular radius C. Next, the cavity is filled with a gelatin dispersion containing dye (or carbon). The dye concentration is formulated to satisfy Beer's law: $D_S(r) = Kr$. The gelatin/dye solution is also formulated to have the same index of refraction as the glass mold, to retain a uniform phase front as light passes through. Finally the glass mold and gelatin are capped by another optical flat to protect the cast gelatin. The outer surfaces of the two optical flats may be given anti-reflection coatings to reduce power losses. All of the techniques described above are standard optical procedures.

At this point two questions occur: can the density K be arbitrarily chosen, and can the gelatin/dye solution be formulated to match the index of refraction of the glass mold? The first question is not a serious problem, at least in the first order solution. The second question is more troublesome. If the indices of refraction cannot be matched then the gelatin mold will act as a convex lens (probably of low power, if the gelatin/dye matches the glass reasonably well). To correct for this the two outer glass surfaces would also have to be ground to counteract the power of the mold. Fortunately there are two free surfaces so at least some of the third order aberrations can be corrected for, and since we have parallel light at normal incidence the combination can probably be corrected perfectly (this correction would obviously add to the cost of the filter; it is worth noting, however, that the two free surfaces can also provide some correction in the case of a non-planar phase front.

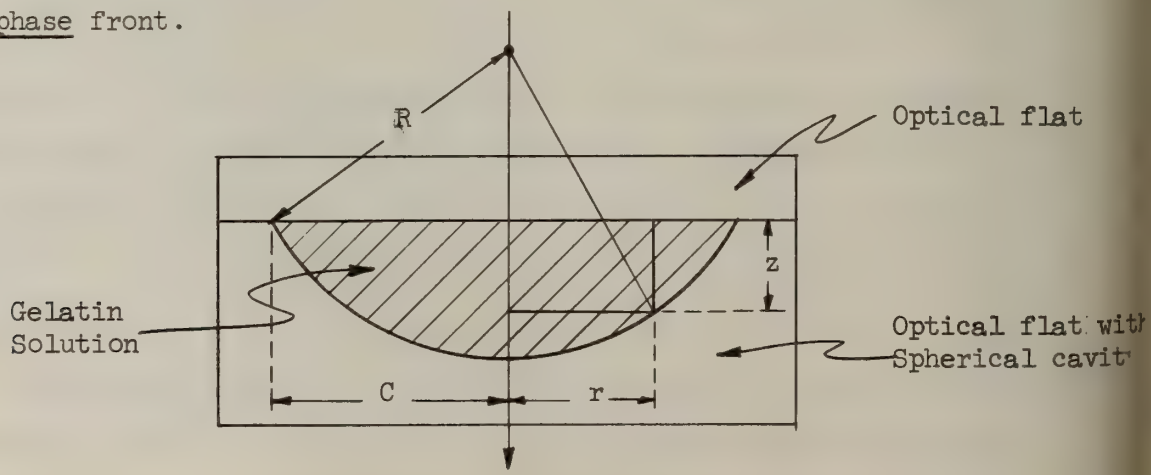


Figure 2. Spherical Gelatin Filter.

For the configuration of Figure 2:

$$Z = \sqrt{R^2-r^2} - \sqrt{R^2-C^2}$$

If $R \gg C, r$, then to the lowest order:

$$Z \cong \frac{C^2-r^2}{2R}$$

This approximates the ideal filter of Section 2.1.5 if we take:

$$D_S(r) \cong K\left(\frac{C^2-r^2}{2R}\right) = 1 - \frac{r^2}{2a^2}$$

i.e.

$$R = Ka^2 \text{ and } C = a\sqrt{2}$$

A higher order analysis and numerical data will be provided in a subsequent report.

****

References

(1) Spectra Physics Laser Technical Bulletin #1, pp. 2, 4.

(2) J. Kreutzer, "Laser Light Redistribution in Illuminating Optical Signal Processing Systems", Chap. 22, Optical and Electro-Optical Information Processing, MIT, 1965.

(3) R. S. Longhurst, Geometrical and Physical Optics, p. 411, Longmans Green and Company, London 1963.

(4) J. J. DePalma and R. D. Pickering, "A Spherical Mask to Compensate for $\cos^3$ and $\cos^4$ Illuminance Variation", Applied Optics 5, 435, March 1966.

2.1.8 Experimental Investigations

The following is a brief outline or the areas to be investigated before the complete system can be tested:

1) One of the first requirements is a power meter to adjust the laser for proper output and to measure light intensity at various points in the system. A total system transmission efficiency of 5% appears reasonable at present.

2) The degree of vibration, its effect on system operation, and possible vibration sources must be investigated. Should diffraction experiments verify that the vibration problem is too severe for optical data processing then the table design will be modified, possibly by attaching a large concrete slab to increase inertial damping.

3) The degree of laser wavefront distortion caused by reflection from the two mirrors at the end of the table will be investigated. Should distortion prove too great and reflection mirrors of sufficient optical quality cannot be obtained then the mirrors will be removed and the length of the table increased by adding more module sections.

4) The problem of switching the laser beam off to inhibit picture integration on the pick-up tube target while the pattern on the crystal is being formed might be solved by mechanically rotating one of the mirrors so that the beam reflects onto the second mirror only after the complete picture has been formed. This possibility will likewise be investigated.

5) Each object placed in the path of the laser beam will have some effect on the wavefront and thus will affect the formation of the Fourier Transform. The effect of wavefront distortion on the quality of optical data processing will be investigated as well as the actual degree of distortion introduced by each element in the light path.

6) The proposed lens system can be readily checked and will be investigated.

7) The KDP crystal is likely the major cause of distortion. Many tests must be run to determine the thickness and crystal constants (electrical and optical), as well as the properties of coatings, mounting substrate and type of cement. Most of these tests will require the vacuum chamber and electron gun.

8) The effects of crystal flatness and uniformity can likewise be investigated, in order to isolate some of the problems involved in

constructing a solid state light valve.

The investigations outlined above will be necessary to help isolate, ascertain, and correct the many problems anticipated in the development of the system. Some of the potential problems, such as crystal uniformity, have occurred in previous work on solid state light valves and as yet few, if any, satisfactory solutions have been found. Other problems, such as wavefront phase distortion, appear uniquely associated with optical data processing systems.

David Casasent
Douglas Sand

2.2 Bandwidth Compression by the △-Method (Project No. 14)

The first goal of this project is to develop a means of detecting the △-Information, i.e., that information which changes between two successive television frames. The second part concerns the bandwidth compression and transmission of the △-information thus obtained. Described herein is the method to be used for detecting the △-information.

A four-track video disc recorder, produced by Colorado Video, Inc., (Boulder), is to be used to store for 1/30 second every complete frame of television information. As each frame of television information is received at the video input, it is simultaneously stored and compared with the information from the previous frame. The △-COMPARATOR provides an output when the two signals being compared disagree, which occurs when some information has changed between successive frames. The output of the △-COMPARATOR is the desired △-information.

In Figure 1, the letters W, R and E indicate WRITE, READ, and ERASE signals, respectively. The incoming video information is stored, alternately, on tracks T_1 and T_2 of the VIDEO DISC RECORDER. As new information is written on one track, the information stored from the previous frame is sumultaneously read by the △-COMPARATOR and erased from the other track. At the beginning of the succeeding frame, the FLIP-FLOP and RELAY DRIVER reverse the sequence. Now the incoming information is stored on the previously erased track, and the stored information is read on the alternate track. The block to the left of the VIDEO DISC RECORDER in Figure 1 illustrates the switching of the WRITE, READ, and ERASE signals between tracks T_1 and T_2. The relay in this block is shown for illustrative purposes only. In the final prototype system, the switching will be accomplished by digitally controlled video gates.

Track T_3 of the VIDEO DISC RECORDER is the master sync. track, on which is prerecorded the horizontal and vertical synchronizing pulses for the television camera (which supplies the signal to the video input) and receiver. Vertical sync. pulses from this track change the state of the FLIP-FLOP at the beginning of each television frame. This FLIP-FLOP controls the switching of the WRITE, READ, and ERASE signals between tracks T_1 and T_2. Actually, a two-to-one count down of the vertical sync. pulses will be necessary to compensate for the two-to-one television interlacing system.

David Rollenhagen.

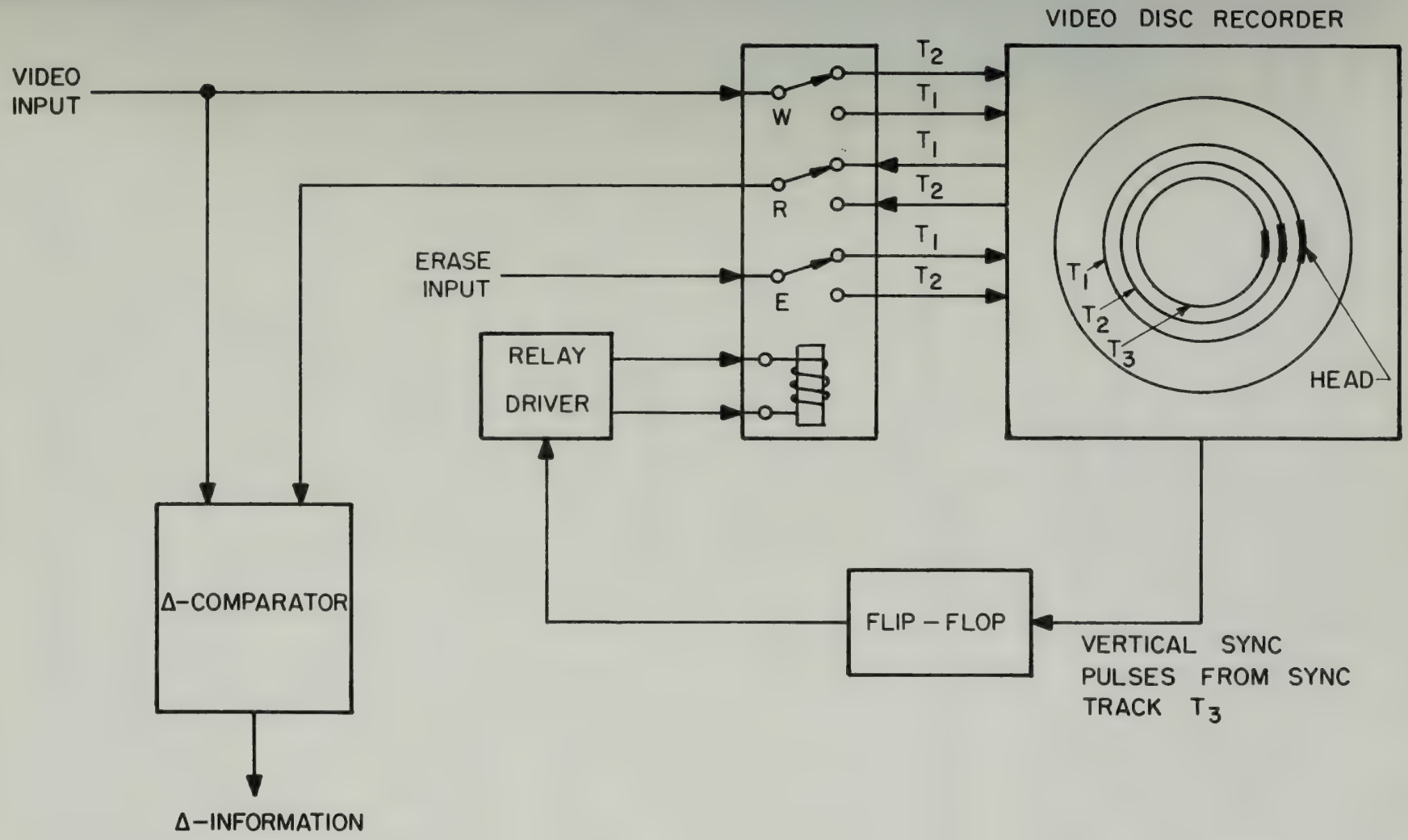


Figure 1. Block Diagram of System Used for Obtaining Δ-Information.

2.3 Functional Encoding (Project No. 15)

2.3.1 General

It was shown in the last report that the bandwidth for transmitting a line drawing with 500 (vertical) line resolution is about 16 kHz times the number of intersections with each horizontal scan. A circle, for example, could be transmitted over a channel of about 32 kHz bandwidth.

The method of encoding the signal has been called functional encoding where each line may be thought of as a function of the horizontal and vertical elapsed time in a TV scan system. There are two major devices in the system. One is the encoder or transmitter, the other is the decoder or receiver. Each one will be described separately.

2.3.2 Functional Encoding Transmitter

In the description of the transmitter reference to Figure 1 will help in the understanding of the system.

A master clock running at 8.064 MHz divides each horizontal line into 512 positions. Hence the horizontal resolution is limited to 512 lines (1024 TV lines). Each time the horizontal scan intersects a line on the drawing a sharp pulse is noted on the video of the camera. These pulses are used to start and stop sequentially the 32 9-bit counters. This gives a maximum of 32 permissible intersections per horizontal scan. The contents of each counter will then represent the elapsed time between video pulses, or distance between lines on the drawing. At the end of each scan the contents of these counters are gated into a set of 32 9-bit registers, themselves sequentially gated to a D/A converter whose output is then the encoded video signal. Since the rate at which the 32 9-bit registers are gated to the D/A converter is less than the rate at which counts are dumped into the counters one can achieve transmission at a reduced bandwidth. Processing delays the video by one horizontal line. Other than that a real time system exists. Figure 2 shows the actual and encoded video signals.

2.3.3 Functional Encoding Receiver

A block diagram of the receiver for the system is shown in Figure 3. The encoded video signal is received and sampled to determine the amplitude of the incoming pulses. The rate of sampling is determined by the number of intersections which are being transmitted. At present this is

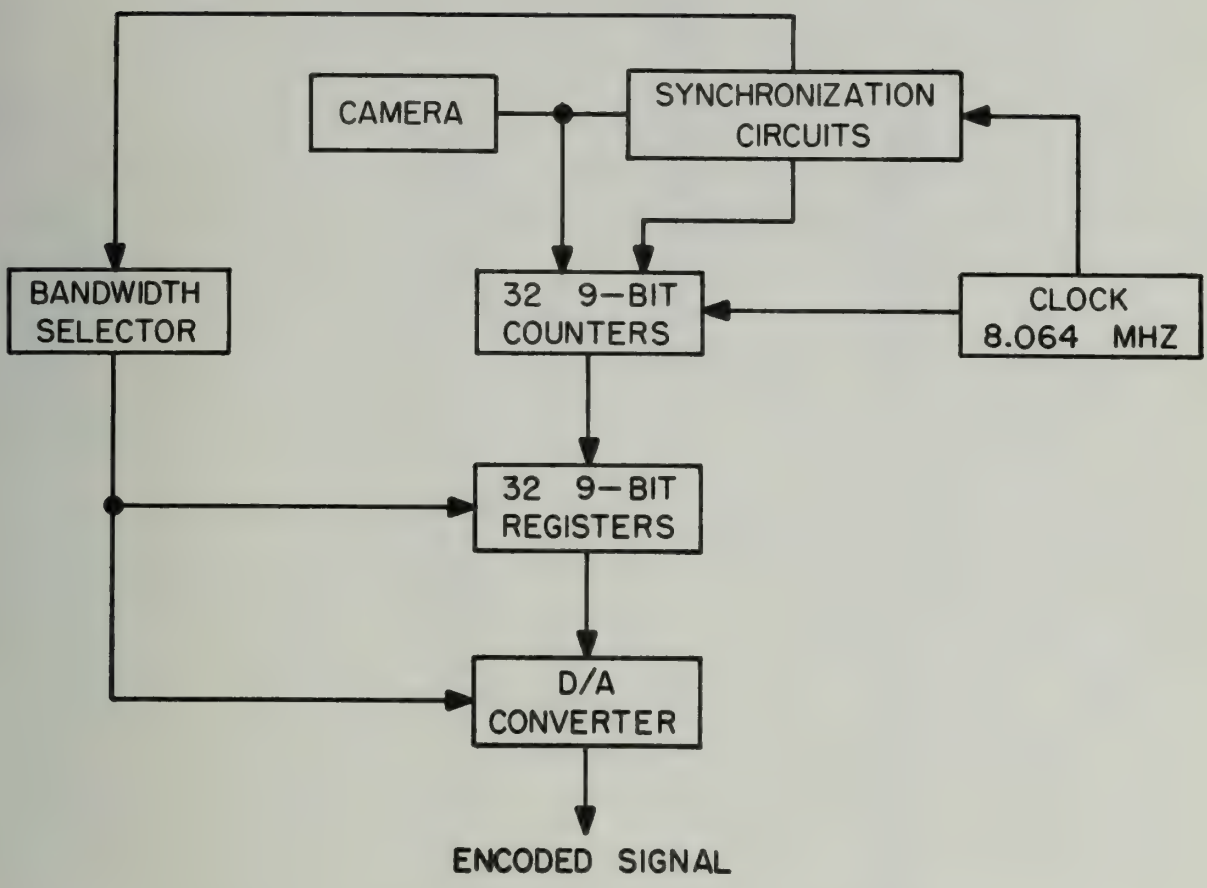


Figure 1. Block Diagram of Functional Encoding Transmitter.

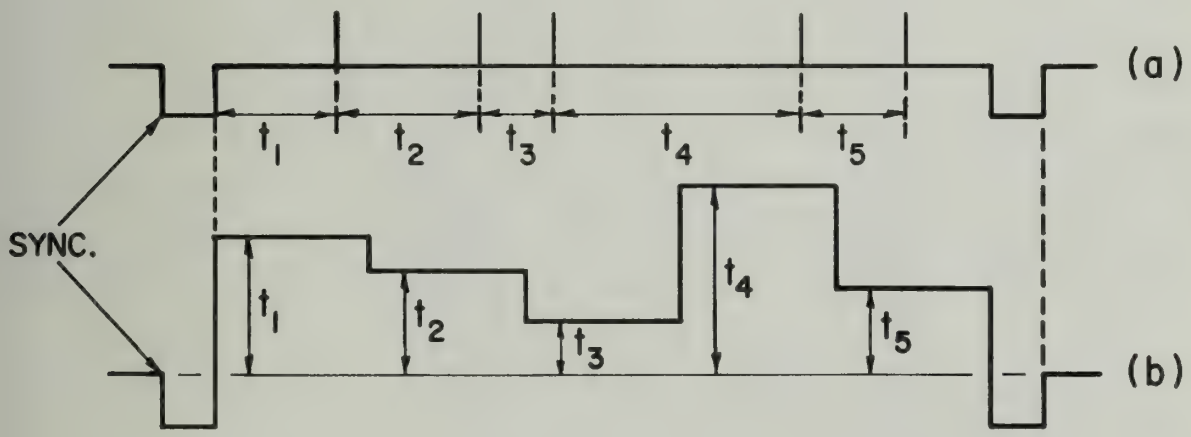


Figure 2. (a) Camera Video; (b) Encoded Video.

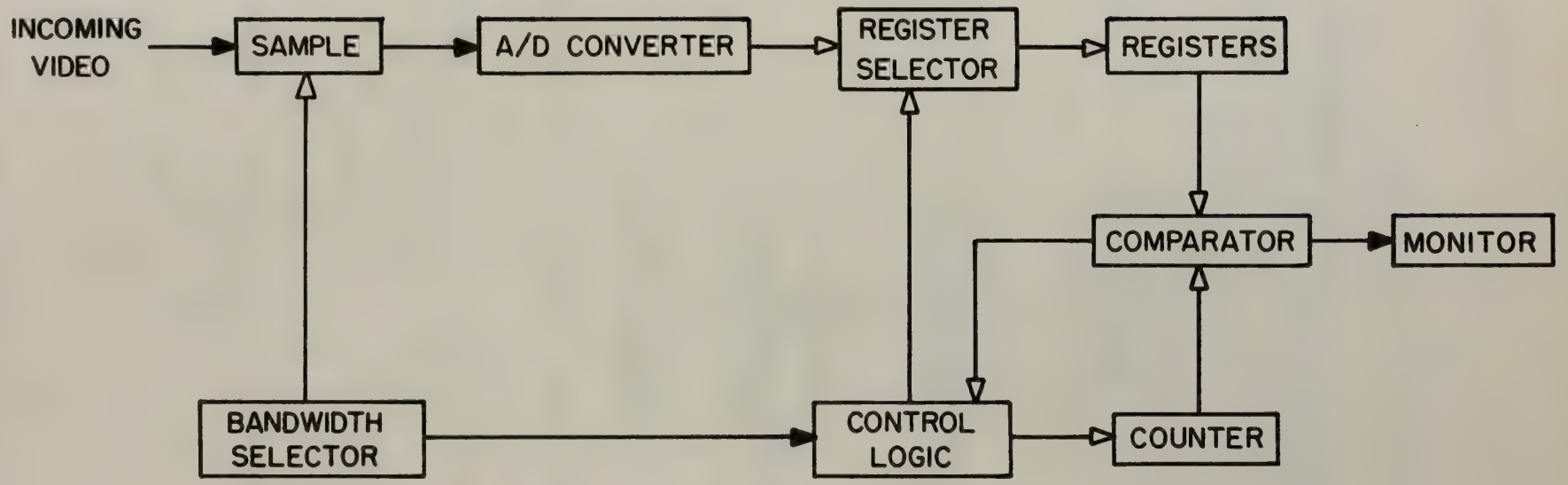


Figure 3. Block Diagram of Functional Encoding Receiver.

accomplished manually by means of the bandwidth selector, but provisions are being included in the system to allow the insertion, at a later date, of an automatic bandwidth selector.

The sampled video is then fed into an analog-digital converter. Since a maximum of 32 horizontal intersections may be received during a line time of approximately 52μs, the rate of information into the analog-digital converter can be as fast as once every 1.6μs. The speed of operation required of the converter, therefore, rules out most conventional designs. Presently a circuit is being designed which can function at the required speed. The transmitted signal has now been decoded, the digital signals corresponding to the elapsed time between horizontal intersections of the video.

The output of the A/D converter is then sequentially gated into 32 9-bit registers. This gating takes place at the same rate as the original sampling of the encoded video so that, for each horizontal intersection, an analog sample is taken, and, consequently, a corresponding digital signal is shifted into a register. A total of 64 registers are available so that while the second line of information is being fed into the registers, the information previously stored may be read out. Then while the third line is being received, the second line can be read out. In this manner, the receiver can operate in real time, with a one line delay.

The read-out process is a rather simple one. The outputs from the registers are sequentially gated into one input of a comparator. When the monitor starts to scan, a counter begins counting at 8.064 MHz and is fed into the other input of the comparator. When the two inputs are equal, a dot is written on the screen, the next output from the registers is gated into the comparator, and the counter is reset and begins counting immediately. Again when the inputs are equal a dot is written on the screen, and the cycle is repeated until the information from all 32 registers has been extracted.

E. Carr
P. Oberbeck
A. Simons

2.4 The Tricolor Cartograph (Project No. 16)

2.4.1 Theoretical Discussion

The goal of this system is to provide automatic coloring for a color display. In accomplishing this coloring some restrictions must be made because of limitations imposed by the hardware used in realizing the system. Generally, these restrictions can be divided between the operator and the system. That is, by placing more restrictions on the operator, the system can often be made simpler. The goal is to make the system as automatic as possible and thus minimize the restrictions on the operator. In any case, for the system to accomplish the coloring the problem must be defined in terms which can be utilized. Thus, the following information must be supplied:

1) The boundaries of all areas which may be colored.
2) Which of these areas is to be colored.
3) The color.

Note that in defining the boundary it is possible for a boundary to extend to infinity. It is also possible that a boundary might be open (and finite) in which case the total area to be colored would consist of the area both inside and outside the boundary. The area which is to be colored and the color must be designated, of course, since these are to be arbitrary choices of the operator.

A point to be considered is whether or not it is necessary to restrict the system to coloring simply connected regions. There is no reason to do so theoretically but practical considerations could (but probably will not) dictate such a restriction.

Thus, in theory, the system has all the required information if it knows which area is to be colored, what the color is to be and where the boundary is. Whether this information is available and in what form is highly dependent on the practical realization which is used. Given the above information the coloring is not difficult from a theoretical point of view. With all boundaries supplied the operator must define the area to be colored. Since there may be many areas, it is necessary to uniquely define one of these. This can be done by encircling it with a pen, by tracing out its boundary or by designating any interior point. From an operator's viewpoint, the simplest of these would be to designate any point inside the boundary. Once any one point inside the area has been determined, all adjacent points

to that point which are not on the boundary are colored. Then all adjacent points to these points which are not on the boundary are colored. Thus, given the starting point, all adjacent points in every direction are examined and colored if they are not boundary points. The process can be speeded up by not coloring points already colored. Note that it is not possible to skip over points since the boundary may pass through one or more of these points. One problem that does arise in this scheme is the difficulty in determining when the area is completely colored. This could be solved by allowing sufficient time to have colored every possible point or by arbitrarily stopping after no uncolored points are found on n consecutive tests. Of course n would depend on the size and would thus be difficult to determine.

It is unfortunate that no practical realization of such a scheme exists which is not unduly complex or expensive or both.

2.4.2 Practical Consideration

For a reasonable resolution there should be about 300 picture elements both horizontally and vertically giving a total of 90,000 elements in the picture. This would correspond to 90,000 digital bits. Without encoding, a memory would be required for each color and one for outlines. This would require 360,000 bits. It is desirable to be able to examine these bits individually so that random access to each bit would be desirable. Since this is not practical either serial access must be employed or some scheme of bringing the bits out in larger blocks (words) and then examining them individually.

Storage methods which are presently available are the disk, tape, drum, core, and storage tubes. The need for local erasure, local writing, and long term storage with continuous output eliminates tape and storage tubes. The high resolution requirement eliminates the drum. Recently, high resolution disks have become available and this has been chosen over the core because of reduced cost and complexity. With this choice the format in which the graphical information appears is fixed and is serial. Since the only readily available display is the standard tricolor tube, a disk and tricolor tube operating at the standard television line frequency will be utilized.

These choices fix the scanning format of the information and it is now necessary to develop a method for performing the coloring within the format, if possible. It is, of course, possible to transfer back and forth between this format and other formats. This can be done with a scan converter in which the mode of scanning can be changed or it can be accomplished by sampling once per frame in the television format. The latter process is too slow and the former results in registration problems in the storage tube when the potentials inside the tube are changed from one mode to another. Although it is possible that this registration problem might be overcome, there are other problems which arise when transferring the information back onto the disk. One of these problems is that of preventing the outlines which by necessity had been transferred to the storage tube initially from being written into the color memory of the disk. In view of these difficulties it is best to stay within the TV format if possible.

As mentioned, there are basically two problems associated with coloring in a given area. The first of these is that of keeping track of which area is to be colored once it has been indicated initially. The second is determining when to start and when to stop coloring inside that boundary. The first results from the fact that there are possibly many areas present of which only the designated one is to be colored. The second arises because the boundary may have cusps, lobes, branches, or lines which are parallel to the scan.

The details of why these geometries cause trouble will not be explored here in depth. However, cusps and lobes appear as one point when scanned and do not convey to the system the fact that the scan has passed both into and out of the area of interest. Branches, cusps, and lobes all cause trouble when utilizing any scheme involving the enumeration of the boundaries. Horizontal tangencies often appear as one long point.

2.4.3. Realizable Methods

One method for realizing the coloring requires that the operator designate all the points between the vertical extremities of the area (just one point per television line, however). This could be done by having the operator trace with the pen the left boundary of the figure. The tracing could be done either to the left of the boundary or directly on the boundary.

The system would then color between the next two boundaries beyond the pen. Several operations would be required of the operator in this case in order to completely color an area of reasonable complexity. There are two drawbacks to this method:

1) The operator would have to be extremely careful not to exceed the vertical extremities of the boundary. To do so would cause coloring of the wrong areas. Also, great care is required at branches in order to assure proper coloring.

2) Too much is required of the operator in terms of the number of operations and these are too restrictive.

A variation of the above would be to allow the operator to designate the extremities on the inside of the boundary. This puts almost as many restrictions on the operator but does eliminate the problem of determining which area to color at branches. One disadvantage of designating the inside of the boundary rather than the outside is that (for scanning from left to right) the left boundary has already been passed over by the time the system determines that it was indeed that last boundary at which it should have begun coloring. It is not difficult to wait one frame and then color on this same line if the left boundary coordinate is stored. The difficulty with this is that it takes 1/15 second per line (20 seconds for 300 lines). This is too long. A way of circumventing this problem is to wait only one line. This, of course, means that the coloring is misregistered by two lines (the system is interlaced).

This misregistration would probably not be intolerable but could certainly be annoying. If this two line misregistration is accepted another method presents itself.

This method would store the coordinates of the pen pulse which represents a point on the interior of the boundary. During the next frame the system would then determine the upper and lower coordinate at that horizontal position. During the following frame all television lines between these two upper and lower bounds would be colored in misregistered by two lines. The major drawback to this method is, of course, the misregistration. However, it does color in a large area automatically. The elapsed time for this coloring is only two frames or 1/15 second which is reasonable. Coloring all of an area would again require that the operator move the pen. But now

the pen could be moved anywhere and, at least in theory, would only have to be pointed at a small number of discrete points to do the entire area. One aspect of this method which may cause trouble is the fact that it will recolor many parts of the area. This could cause some registration or intensity problems. However, it is no doubt possible to inhibit coloring in areas which are already colored.

It appears then that the latter method is the reasonable compromise between all the interacting requirements. The storage of the coordinates can be accomplished with digital, analog, or hybrid circuitry. It has not been determined which of these approaches will be taken. However, the digital implementation would provide stability and speed. Whether an analog system could do as well must be investigated.

William Kubitz

3. SOFTWARE SYSTEMS RESEARCH PROGRAM

(This work is supported in part by Contract No. AT(11-1)-1469 of the Atomic Energy Commission and in part by the University of Illinois.)

3.1 BOOTS Time Sharing System

Work continued in January on the BOOTS time sharing system, with considerable success. FORTRAN now compiles programs and appears to link into the overall BOOTS system correctly. The binary loader was interfaced into the system but has not been checked out as yet. It is now possible to obtain 1403 listings and punched output of files resident on the disk: putting files on the disk from an input tape is still not feasible. The garbage collector for file space on the disk is programmed and partially checked.

Three major commands are now working in February, one more remains to be debugged. The lucky three are NICAP, FORTRAN, and SHAZAM; the laggard is RUN.

It has always been possible to generate NICAP of FORTRAN programs within the BOOTS filing system. The commands NICAP FILE and FORTRAN FILE now allow you to obtain assemblies and compilations of these programs with an automatic listing of any fatal errors. For example, given a file named ALPHA, by typing the command NICAP ALPHA you bring the NICAP assembler into core and have it attempt to assemble ALPHA. The assembler will produce a binary file suitable for loading by the relocatable binary loader, a listing of its assembly which can be printed offline (but not at the console at this time), and a listing of any fatal errors it detected during assembly. If no fatal errors were found the assembly will terminate normally and the message NO FATAL ERRORS will be printed, signifying the end of the assembly. If fatal errors are found the message FATAL ERRORS is printed. At this point you can have the file of fatal errors printed by giving the FATAL command; if you already know what they are from careful introspection and examination of the program you need not have them printed. FORTRAN ALPHA works in precisely the same way. Note that it is up to the user to make sure that files handed to the FORTRAN compiler are actually written in FORTRAN. The compiler is perfectly happy to try to compile anything.

The SHAZAM command is actually disallowed to all non-system users, but it is one of the most important commands in BOOTS. When a system user gives this command, BOOTS expects an input tape hanging on Unit 9, and, given that a properly prepared tape is there, will input every file on the tape into the filing system, automatically line numbering each file and saving it under the specified file name in the specified user's file dictionary. The 1st card of each file on the tape is not input with the file, but contains in cols. 27-32 the file name the file is to be saved under and in cols. 55-60 the first half of the two-part user identification name of the user in whose file dictionary the file is to be saved. The preceeding gobbeldygook means it is now possible to input card decks into the BOOTS filing system.

The RUN command, which 'almost' works, takes the form RUN A B C D ... where A,B,C etc. are names of files which the user wishes run as a core load. BOOTS takes the binary for each of the files named and hands the lot over to the binary loader, which generates a core load from them and executes it. If any of the files named has no binary an error message is output and the run is aborted. It will also be possible to declare input and output files for the running core load.

In March the overall system reached a level of operation where it was felt it could go public within a few weeks, barring any unforeseen disasters, which, of course, occurred. NICAP, FORTRN, and RUN all work, within limits, but all in all, things are fairly rosy. Many user suggestions have been taken under advisement, which generally is very bad practice; many of the suggestions are being implemented, however, which is even worse.

L. Greninger

A programming memorandum has been prepared on the time share binary loader and will be distributed soon. The loader has been incorporated into the time share system and has been tested without the use of the library as yet.

M. A. Berg

A few more errors in Shorttran were corrected and some programs will run; however, upon further tests, more errors showed up. Debugging routines will be added and the whole package will be run now that the source decks have been reproduced.

J. Christopher

Changes were outlined for the PDP-7 SPU processor to update it for the new BOOTS system. Several new PDP-7 commands were added and will be described in a forthcoming memorandum. A complete description of the PDP-7 SPU processor will be completed in may.

A. Otis, Jr.

3.2 System 360 Console Planning

Work continued on setting up specifications for the PL/I console compiler. I finished writing up a list of the restrictions I thought it would be reasonable to impose.

A document attempting to define the syntax of the console version of PL/I to be implemented was produced using the IBM PL/I specification as a reference. Indications were made to any restrictions in the use of the statements allowed which differ from the original specification.

A bit-significance table and the output from the syntax scan were worked out for the DECLARE statement. A flow-chart for the actual syntax scan of DECLARE statements was started; it will operate by checking the bit significance table for the given identifier for information about previous attributes for every attribute input, and check for compatibility.

A format for the output from the syntax scan for DO statements was also worked out. It is similar to the DECLARE statement output in that the output string is of fixed length and consists of pointers to the information about the nature of the DO group.

J. L. Christopher

The majority of the syntax-scanner for the arithmetic assignment statements of the console implementation of PL/I on the IBM 360 has been flow charted. These flow charts are being coded for the IBM 7094 for testing of the syntax scanner. The coding is being done using macro instructions to facilitate the changeover from the 7094 to the 360. The majority of coding which has been written is for I/O and data manipulation within the 7094 to make it compatible with the 360.

W. W. Demlow

Work continued on restricting PL/I to a feasible remote console language. The final result will be oriented to numerical calculations.

Presently several macros which will simulate 360 assembly language instructions are programmed to run on the 7094. Also a basic Scatre program to convert an arithmetic expression into reverse Polish notation is in the advanced debugging stages. This program also serves the dual purpose of checking the macros previously mentioned.

M. Meyers

3.3 Computer Graphics

3.3.1 Computer Aided Programming System

Files 725-1 and 725-2 were written this quarter. File 725-1 provides a general problem definition in the area of computer aided programming systems. File 725-2 gives a description of a possible solution (CAPS) to the problem defined in File 725-1. Currently in preparation is a file to describe the specifics of such a system implementation on the Digital Equipment Corporation's programmed buffer display-type 338 (PBD-338). This file gives a description of specific operating characterists, data organization, display representation, and data manipulation for CAPS. Also given in this file are specific suggestions for implementation.

Implementation of this system on the PBD-338 is in the coding phase. It is expected that some perturbation of the system design will be a result of further efforts at coding and checkout. With reasonable progress, the initial set of programs should be ready for checkout by the delivery date of the PBD-338, which at this time is April, 1967.

The system that will reside in ILLIAC II as the main computer system for CAPS (see File 725-2) is currently in the design phase. A goal for this system is for the user to be able to create flow chart programs at the terminal and then submit these flow chart programs to the ILLIAC II in order to have them compiled into operating programs. Once these flow chart programs are compiled then they may be run with the user interacting with them in an on-line manner.

Currently under investigation is the scope of facilities needed by the main computer (in the form of subroutines in the ILLIAC II) to process a flow chart program written in a language L. The language L is not rigidly fixed in content but is able to accept new forms and new ideas suggested by the investigation of needed computer facilities. At the same time, the language L is being studied and this language suggests needed main computer facilities.

Currently in favor for the language L is some sort of language that is similar to Fortran or Algol in syntax but has much broader semantics. An example of this type of language is the Iverson language, where the statement A = 10,11,12,13,14; defines A as an array with A(1) = 10, A(2) = 11 and so on. Then in any subsequent statement B = A+C; then B is also any array.

Implementation for a language with this broad form of semantics is tentatively based on a machine design derived from the code word concept of Iliffe.

Actual implementation will be on a simulator running on ILLIAC II. Thus for implementation on any other computer, only the simulator need be recoded.

For the future, more study of the language L and the needed facilities which will result in a specific implementation proposal. Once a proposal is accepted, implementation can begin.

3.3.2 NEPAL Assembler

Planned, coded and partially debugged this quarter is an assembler for the PDP-8. The assembler runs on the ILLIAC II. The input to the NEPAL assembler is symbolic PDP-8 programs punched on cards. The assembly language is a subset of PAL III, the language of the DEC supplied PDP-8 assembler. The output of the NEPAL assembler is an assembly listing, listed on the 1403 printer and an object program tape (binary paper tape) ready for loading into the PDP-8. The assembler currently assembles programs, but does not provide error diagnostics or punched paper tape. These omitted facilities have the highest priority for implementation.

The reason for this assembler over the DEC supplied assembler is primarily one of speed. The PDP-8 reads and punches paper tape at 10 characters per second. The 1402 reads cards at 600 cards per minute, the 1403 prints listings at 800 lines per minute and the ILLIAC II punches paper tape at 100 characters per second.

Using the NEPAL assembler the symbolic program decks can be edited in a normal fashion and then assembled, requiring that the program be read once. The listing and object paper tape are then available.

To get an assembly on the PDP-8 requires 4 complete passes over the source symbolic program paper tape. (One reading and one punching is required for editing the source tape. Two readings of the source tape are required for an assembly.) To get an assembly listing requires an additional reading of the source tape.

The length of time required to get an assembly with the NEPAL assembler is 10 - 20 times shorter than the length of time required for the same assembly on the PDP-8.

3.3.3 PDP-8 Resident System

In the planning and coding phase this quarter is a set of PDP-8 routines designed to form a resident system for the PDP-8. The functions in this system are: I/O routines with local console, I/O routines with PDP-7/630 interrupt processor, magnetic tape system loader, paper tape loaders, and display initialization.

The magnetic tape loader and paper tape loaders are supplied by DEC and are incorporated into our resident package. These loaders are not callable as subroutines but are manually addressed from the switch register of the PDP-8. The remaining routines are coded and are being debugged.

The interrupt processor enables each user program to specify what action is to be taken on each interrupt. An interrupt condition A may be ignored or the user program may specify an address of a subroutine that is to be executed upon being interrupted by condition A. This allows a user to control the interrupt conditions without having to write an interrupt processor Also the actions to be taken upon a given interrupt condition may change dynamically as the user program executes.

Both sets of I/O routines send lines of characters to or from the specified location (remote or local). The lines may be deliniated with a bell character or a carriage return depending on which routine is used.

The display initialization routine initializes the display to a present set of conditions and then starts the display into action. Each user may specify initial conditions or rely upon the system's initial conditions.

F. K. Richardson

3.3.4 ILLIAC II - PBD-338 Communications

A Nicap subroutine to transmit plot information and information for drawing alphanumeric and special symbols from the ILLIAC II to the 338 display unit has been completed. This subroutine follows the pattern of the present CCP1PL and CCP2SY routines for CalComp plotting with corresponding entry points. The basic function of this routine is to format plotting information into a 12 bit format for use in plotting on the 338 display unit supplying control words to enter data or control state and set the appropriate mode (i.e. point, vector, or character).

The plot portion of the subroutine does not restrict the plot to the size of the screen. If a specified X or Y coordinate exceeds the screen size, the plot is made to the point at which the vector would leave the screen. When the coordinates are again in range, the intercept for re-entry is computed, and the vector is drawn to the new coordinates.

That portion of the subroutine which corresponds to CCP2SY formats the data for use by the VC38 dispatch type character generator of the 338 display. The calling sequence for this entry point is identical to that of CCP2SY although, at present, no provisions are made for the rotation of characters. Four size settings are permissible: 0.045, 0.09, 0.18, and 0.36 inches. It will be possible to have up to 128 characters available by use of the 6-bit format and upper and lower case of the character generator.

An addition was made to the PLOT routine for PBD-338 - ILLIAC II communication which will permit the user to draw on the 338 screen and receive the coordinates of the curve drawn in ILLIAC for analysis purposes.

Planning was begun for a program which will decode the SOURCE file which is a compacted version of the DISPLAY file (actual set of PBD-338 instructions that cause display processor to generate prescribed display) and generate the display on the CalComp plotter.

The Nicap program to decode the SØURCE file used in PBD-338 display and generate the display on the CalComp plotter was written and completed.

L. L. Koopman

3.3.5 Tracking the Light Pen

The tracking cross acts as a text cursor or marker. It should be able to be positioned at an arbitrary point of the display screen by using the light pen. Therefore, it allows the user to edit characters within a line without having to retype the whole line.

The tracking cross is displayed in vector mode with a non-intensified point as its starting point. This point is crossed by both the horizontal and vertical vectors which form the tracking cross. Hence changing the coordinates of this point will cause the position of the tracking cross to be changed when the display is resumed after an interrupt.

At first, INTERRUPT system is turned on, then the light pen is enabled and it will cause the PDP-8 to be interrupted when the light pen senses light. The INTERRUPT routine decides which one causes the interrupt. If light pen hits interrupt is detected, the control is transferred to the light pen interrupt handling routine. This routine detects on which symbol the light pen hits. If it decided that the tracking cross is sensed by the

light pen, then the control is transferred to the light pen tracking program to update the coordinates of the starting point of the tracking cross so that the movement of the tracking cross can be made by light pen.

In order to get some idea about the computer display system, a study was made on Section II (on computer display fundamentals) of the Computer Display Review published by Adams Associates, Inc.

Work has started on the 338 end of the CAPS system. In particular, the DRAWIN (drawing) routine for constructing the display file (DispLA) table, and the display location table (DISLOC) is being programmed.

Work continued in February on the DRAWINg program at the PDP-8 end of the CAPS system. The function of the DRAWIN program is to be used to convert the information in the SOURCE file into a necessary display file for PBD-338 to display symbols and other information contained in the SOURCE file. A DISLOC (DISplay LOCation) table is also to be constructed by the DRAWIN program so that necessary information can be got to display an ARROW symbol.

The major parts of the DRAWIN program with the subsidary routines have been coded. The subsidary routines included those for calculating the starting points for text display as well as those to display flow chart symbols. Things left out are a routine to display an ARROW symbol and the implementation of the "CHANGE" facilities of the DRAWIN program. The latter is temporarily postponed. A scheme to program the ARROW-display subroutine has been developed and flow-charted. Work is now started on detail coding of this subroutine.

Two subroutines of the drawing program to handle arrow symbols has been completed. The whole drawing program for generating display file for PBD-338 from user's or ILLIAC II's source table has been checked out on PDP-8. It seems to work correctly. The final modification will be done after the PBD-338 is available.

A characters generator routine with its dispatch table was completed in March. The characters are to be drawn in short vector mode. The dispatch table was arranged in BCD code order. Since the teletype of PDP-8

is using ASCII code, a routine to convert ASCII to BCD and BCD to ASCII is therefore needed. This routine has been completed also in this month.

T-Y Lo

3.3.6 Non-Graphical Specification of Figures

A project to design a language, suitable for card, paper tape or typewriter input, which can specify graphical information has started. The program is being written in FORTRAN for CalComp output to be run offline, but online capabilities will be added when the DEC 338 system is operational.

The graphics display language has been formulated in an outline format to provide for simple initial assembling. The execution program is now completely written and in the testing stage. The impending availability of a display console for the ILLIAC II will make possible online experience with the package, providing guides for further development.

A. Henderson
C. W. Gear

All plotter routines for G.D.L. have been written, coded and are being debugged. The approximate length of the routines is 2000 cards. The assembler will be written in FØRTRAN with a machine language subroutine.

J. E. Roman

3.3.7 Remote Console Design

Preliminary work was begun on the sophisticated console, trying to define some of the hardware needs by examining the capabilities expected of the console; roughly, the hoped-for capabilities include local language processing, including syntax checking and interpretive execution, graphics, and low-level text editing. Nothing definite has emerged yet as to the structure of the machine, but at present it looks like a fairly slow, small, microprogrammed machine executing its macroprograms from a disk which is also used for graphical display regeneration. A simulation model, to be implemented on the PDP-8, is planned.

A possible design for a 'cheap' console embodying a disk, display, core memory and about 10 sixteen bit registers in the data flow was investigated. It is shown in the diagram below. The core memory would be used for micro program and for data storage. The disk would be used to refresh the display, to hold data and replacement microprogram. A basic cycle would consist of two core cycles equivalent to 8 subcycles (a data transmission from register to register). The subcycles will be used for micro code fetch, data fetch, display update, disk input or output and an arithmetic cycle.

L. Greninger
C. W. Gear

3.4 Automatic Numerical Analysis - Ordinary Differential Equation System

A program has been written to calculate the error constant of a general linear K-step method for integrating differential equations. The method is of the form:

$$\alpha_0 y_{n+1} + \alpha_1 y_n + \alpha_2 y_{n-1} + \ldots + \alpha_K y_{n+1-K} =$$

$$h(\beta_0 y'_{n+1} + \beta_1 y'_n + \beta_2 y'_{n-1} + \ldots + \beta_K y'_{n+1-K})$$

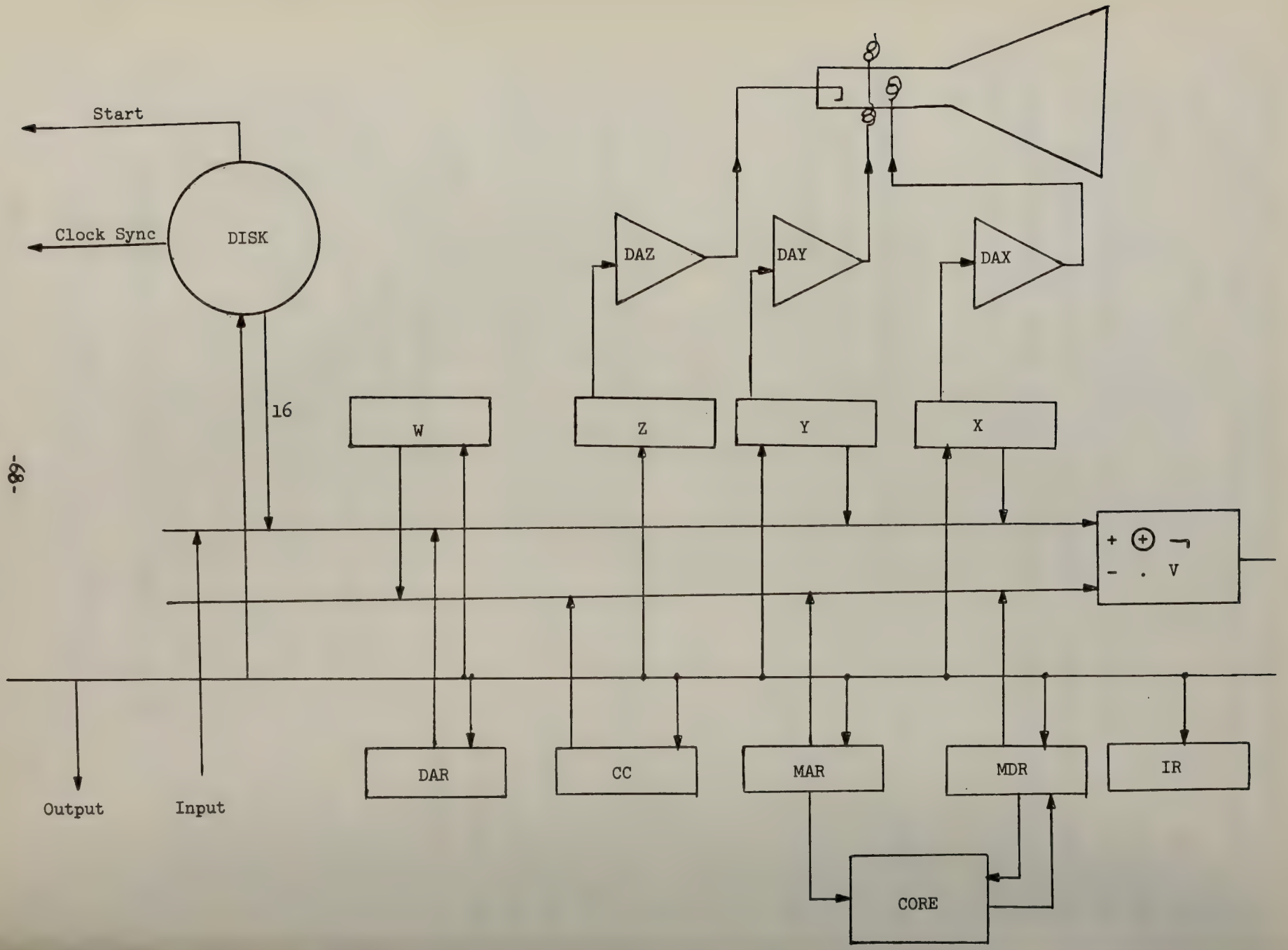
The error in the above method is of the order of $C_{p+1} h^{p+1} y^{(p+1)}(\theta)$. Given the coefficients α_i, β_i, $(i = 0,1,\ldots K)$, the error constant, E, is found in the following way:

Calculate C_i $(i = 0,1,\ldots p+1)$ where C_{p+1} is the first $C_i \neq 0$,

$$C_0 = \alpha_0 + \alpha_1 + \alpha_2 + \ldots \alpha_K$$

$$C_1 = \alpha_K + 2\alpha_{K-1} + \ldots + (K-1)\,\alpha_2 + K\alpha_1 - (\beta_0 + \beta_1 + \beta_2 + \ldots + \beta_K)$$

$$C_p = \frac{1}{p!}(\alpha_K + 2^p \alpha_{K-1} + \ldots + (K-1)^p \alpha_2 + K^p \alpha_1) - \frac{1}{(p-1)!}(\beta_K + 2^{p-1}\beta_{K-1} + \ldots + (K-1)^{p-1}\beta_2 + K^{p-1}\beta_1)$$


Start
Clock Sync
DISK
16
DAZ
DAY
DAX
W
Z
Y
X
+
-
V
DAR
CC
MAR
MDR
IR
Output
Input
CORE

$$\text{then } E = \frac{C_{p+1}}{(\beta_0 + \beta_1 + \ldots + \beta_K)}$$

In particular, the error constants being calculated pertain to specific stiffly stable methods of order K where the α_i and β_i are related as follows:

$$\sum_{i=0}^{K} \alpha_i (X+1)^{K-i} = \left[\log (X+1) \cdot \sum_{i=0}^{K} \beta_i (X+1)^{K-i}\right]_K$$

where $[f(X)]_K$ represents the first KH terms in a power series expansion of f about X = 0.

Some changes have been made in the program used to investigate the stability and accuracy of various order linear methods for integrating first degree ordinary differential equations:

$$\alpha_0 y_{n+1} + \alpha_1 y_n + \ldots \alpha_K y_{n+1-K} = h(\beta_0 y'_{n+1} + \beta_1 y'_n \ldots \beta_K y'_{n+1-K})$$

The changes are as follows:

1) The error constant associated with a method of particular order, K, and coefficients of y'_i (i.e. β_0, $\beta_1 .. \beta_K$), was previously determined as a floating point number and is now expressed as the rates of two integers.

2) The coefficients of y_i (i.e. β_0, $\beta_1 \ldots \beta_K$), which were previously expressed as floating point numbers, are also given in the form p/q where p and q are integers.

3) The program as described in an earlier report used the CalComp plotter to plot the locus of:

$$\frac{\sum_{i=0}^{K} \alpha_i (Re^{i\theta})^{K-i}}{\sum_{i=0}^{K} \beta_i (Re^{i\theta})^{K-i}}$$

in order to determine the stability of a particular method. The method is dependent upon the parameters $\beta_0, \beta_1 \ldots, \beta_K$ and K.

Due to the amount of time necessary to obtain a plot for a single set of parameters, the program has been adapted for using a storage tube oscilloscope to produce the desired graph instead of using the plotter. In this way new parameters can be entered on a teletype and a new plot is obtained almost immediately.

The above change involved changes in the plot program by R. Lyon and modification of Print and Sysio by G. Huszar and L. Greninger.

The change in the program used to investigate the stability and accuracy of various order methods for solving differential equations which was previously reported (the rationalization of coefficients and error constants) has been found to be effective in dealing only with methods of order eight and lower. A few minor changes are being made to extend the procedure up to methods of order twenty.

It has been found that a variation in the $n+1^{\underline{st}}$ coefficient used as input in the above-mentioned program does not effect a change in the error constant associated with the method generated.

The investigation of stability of particular methods and the attempts to locate optimal input coefficients which generate these methods have been unsuccessful, apparently due to some difficulty in using the MSR. This will be avoided by use of the PBD-338 when it arrives.

Study is continuing on the problem of applying the methods being presently investigated to higher order differential equations.

K. Walsh

The analytic study of stiff O.D.E.'s reported in Report #221 only dealt with a single equation of the first order. While it is fairly certain that the methods developed will apply to systems of equations of various orders, that result remains to be proved, and parameters have not yet been found for higher order equations.

Systems of first order equations were examined with a view to showing that stiffly stable methods for single first order equations are also stiffly stable for systems. The same method is used for each member of the system, the result is almost trivial, but if different methods are used for each member of the system, the result has not been shown.

Suppose that for the i-th equation

$$\frac{dy_i}{dx} = f_i(x,y_1,y_2,\ldots y_s)$$

the method

$$\alpha_{0,i}\, y_{n,i} + \alpha_{1,i}\, y_{n-1,i} + \ldots + \alpha_{K,i}\, y_{n-K,i} +$$

$$h(\beta_{0,i}\, y'_{n,i} + \beta_{1,i}\, y'_{n-1,i} + \ldots) = 0$$

is used, i = 1,2,...,s. The true solution $y^T_{n,s}$ satisfies a similar equation with a truncation error term T_i added. By subtracting and setting the error $\varepsilon_{n,i} = y_{n,i} - y^T_{n,i}$ we get the difference equation for $\varepsilon_{n,i}$ in the form

$$\alpha_{0,i}\, y_{n,i} + \alpha_{1,i}\, y_{n-1,i} + \ldots$$

$$+ h\beta_0 \left(\frac{\partial f_i}{\partial y_1}\, \varepsilon_{n,1} + \frac{\partial f_i}{\partial y_2}\, \varepsilon_{n,2} + \ldots \right)$$

$$+ h\beta_1 \left(\frac{\partial f_i}{\partial y_1}\, \varepsilon_{n-1,i} + \frac{\partial f_i}{\partial y_2}\, \varepsilon_{n,2} + \ldots \right)$$

$$+ \ldots.$$

$$= T_i \qquad (1)$$

The $\frac{\partial f_i}{\partial y_j}$ are evaluated at various points in a region around the true solution in the interval $x \varepsilon [x_{n-k}, x_n]$. Neglecting terms of order h^2 (and requiring

continuous derivatives of the $\frac{\partial f_i}{\partial y_j}$), these can all be evaluated at the same place. Write

$$\rho_i(\xi) = \sum_{q=0}^{K} \alpha_{q,i}\, \xi^{K-q}$$

and

$$\sigma_i(\xi) = \sum_{q=0}^{K} \beta_{q,i}\, \xi^{K-q}$$

By looking for a trial solution of the form

$$\varepsilon_{n,i} = A_i \xi^n$$

in (1) with the truncation error T set to zero, we get the equation

$$A_i \rho_i(\xi) + h \sum_{j=1}^{s} A_j \frac{\partial f_i}{\partial y_j} \sigma_i(\xi) = 0.$$

This is a system of linear homogeneous equations in the A_i, and therefore only has a non-trivial solution if the determinant below is zero.

$$\begin{vmatrix} \rho_1(\xi) + h \frac{\partial f_1}{\partial y_1} \sigma_1(\xi) & h \frac{\partial f_1}{\partial y_2} \sigma_1(\xi) & h \frac{\partial f_1}{\partial y_3} \sigma_1(\xi) & \cdots \\ h \frac{\partial f_2}{\partial f_1} \sigma_2(\xi) & \rho_2(\xi) + h \frac{\partial f_2}{\partial y_2} \sigma_2(\xi) & h \frac{\partial f_3}{\partial y_3} \sigma_2(\xi) & \cdots \\ h \frac{\partial f_3}{\partial y_1} \sigma_3(\xi) & \cdots\cdots\cdots\cdots & & \end{vmatrix}$$

This is a polynomial equation of degree S * K as expected. Since we are only interested in the roots of this determinant, divide the i-th row by $\rho_i(\xi)$. Then the matrix will have the form $I + h\sum F$ where I is the s * s identity matrix, F is the matrix of partial derivatives $\frac{\partial f_i}{\partial y_j}$ and $\sum$ is the

diagonal matrix whose i-th diagonal element is $\sigma_i(\xi)/\rho_i(\xi)$. Suppose that S is a matrix which reduces $\sum'F$ to an upper triangle matrix under a similarity transformation, then the roots of the determinental equation are the roots of $|S^*(I + h\sum F)S^{-1}| = 0$ or $|I + h\Delta| = 0$ where $\Delta = S\sum S^{-1}$ is upper triangular. This is equivalent to a system of S equations, one for each diagonal element. If all of the ρ_i and σ_i are the same, then $\sum = I\sigma(\xi)/\rho(\xi)$ so that the diagonal elements of Δ are $\lambda_i\ \sigma(\xi)/\rho(\xi)$, where the λ_i are the eigen values of F. Hence the roots are the roots of

$$1 - h\lambda_i\ \sigma(\xi)/\rho(\xi) = 0$$

which is as expected from the single equation analysis. Are the roots of this simple form when not all of the ρ_i and σ_i are the same?

C. W. Gear

3.5 File Numbers, Reports, Programming Memorandums, and Publications Completed This Quarter

1. Carter, C. E., "Some Information from Bell Telephone," D.C.S. File #722, February 23, 1967.

2. Richardson, F. K., "Graphical Computer Programming: Two Dimensional Programming Languages," D.C.S. File #725-1, January 12, 1967.

3. Richardson, F. K., "CAPS: Computer Aided Programming," D.C.S. File #725-2, January 12, 1967.

4. Otis, A. B., Jr., "The Analog-Digital Programming System," D.C.S. File #726, February 23, 1967.

5. Gear, C. W., "Numerical Integration of Stiff Ordinary Differential Equations," D.C.S. Report #221, January 20, 1967.

6. Berg, M. A., "Time Share Binary Loader," Programming Memorandum #53, February 26, 1967.

7. Fisher, R. O. and Shepard, C. D., "Time Sharing on a Computer with a Small Memory," Comm. of the ACM, 10, 2, pp. 77-81, February, 1967.

4.1 Evaluation of the Phase I Study Program Designs

The design proposals for ILLIAC IV were received from the three Phase I contractors, Burroughs, RCA, and UNIVAC, on December 15, 1966. Table I summarizes the salient features of the three designs. These proposals were studied and evaluated by members of the University of Illinois staff and the technical advisory committee for ILLIAC IV. Each evaluator scored the proposals according to criteria for hardware, systems design, bench-mark program performance, environment factors, operation support, contract management, and optional secondary memory capabilities. The resulting combined scores follow:

Burroughs	80.0
RCA	54.4
UNIVAC	47.6

The conclusion of the evaluation was that the Burroughs design represented a substantially superior machine both in computing capacity and in hardware. Negotiations with Burroughs for the Phase II fabrication contract are now underway.

SUMMARY OF ILLIAC IV DESIGNS

	Burroughs	RCA	UNIVAC
I. PROCESSORS			
Number of PE/control unit	64	8	---
Number of control/unit system	4	8	---
Number of PE/system	256	64	256
PE word length	64 bit	32 bit	64 bit
Arithmetic Speed			
a. Floating add	240ns(240ns)*	250ns	400ns
b. Floating multiply	400ns(560ns)*	650ns	400ns
c. Floating divide	2100ns(1050ns)**	950ns	3500ns
Number of Index Reg/PE	1	3	1
Number of Arithmetic registers/PE	3	3	3
II. LOGIC DEVICES			
Type of circuit	ECL	ECL	ECL(E^2CL)
Delay	3ns	5.0ns pair delay	3ns(3ns)
Clock	40ns	50ns (2-phase)	---
IC packages	30-80 gates/circuit	4 gates/chip	2-8 gates/chip
Card size	circuits are directly mounted on board	7" × 8" 120 pin-card	3.37" × 3.26" 56 pin-card

* for two simultaneous 32-bit operations

** estimated.

		Burroughs	RCA	UNIVAC
III.	MEMORY			
	Types of memory	Thin film	Thin film	Thin film Core memory Wire memory
	Cycle time	250ns	220ns	250ns (Thin film)
	Capacity/system	3.2×10^7 bits	0.4 bits	1.6×10^7 ---
IV.	INPUT-OUTPUT			
	Type of memory	Disk	Drum	not specified
	Access time	35ms	8.6ms	not specified
	Transfer rate/system	400mc/s	128mc/s	not specified
	Capacity	10^9 bits	10^8 bits	not specified
	Proposed control computer	B-6500	Spectra 70/55F	Two Univac 1219's
V.	PHYSICAL PROPERTIES			
	Power	110v 60 cycles	440v 400 cycles	120-208v 400 cycles
	Power/PE	18.5kw/PE	18kva/LC	1kw. chassis
	Power/system	653kw/system	162kva/system	700kw/system
	Floor	80 ft. x 24 ft.	57 ft. x 37 ft.	---

Timing of Sample Problems

		Burroughs	RCA	A†
A.	Matrix inversion (dimension 525 x 525)	2.75 ~ 3.84 seconds	29 seconds	
B.	Fourier coefficient computation (4096 sample points)	.487 ~ 0.889 milliseconds	6.5 milliseconds	
C.	Difference equation (5 variables for 128 x 64 mesh points)	0.307 ~ 0.465* milliseconds	38.6 milliseconds*	

---

* Errors in programming observed, RCA timing too slow. Burroughs timing too fast.

A† UNIVAC not submitted.

4.2 Hardware Design

4.2.1 ILLIAC IV Design Optimization

Efforts were made to evaluate preliminary ILLIAC IV design in terms of two distinctive types of codes: the differential equation type and the matrix type.

Several measures for further ILLIAC IV speed improvement were proposed and implemented.

A factor of 1.4 to 2.0 in the speed improvement was expected.

4.2.2 Types and Frequencies of Operations

The present versus expected dynamic frequencies of operations in the two types of codes, hereafter called D-type and M-type, are shown in Figures 1 and 2.

The D-type code requires 2.7 milliseconds to execute a series of 5,800 operations in which 4,500 LOAD, ADD and MULTIPLY operations dominate.

The M-type code which employs Gaussian elimination methods requires, for inversion of a 525 x 525 matrix, 3.75 milliseconds in scaling all the elements of the matrix. Indexing, which is mostly executed in the control unit, dominates in the computation as shown in Figures 1 and 2.

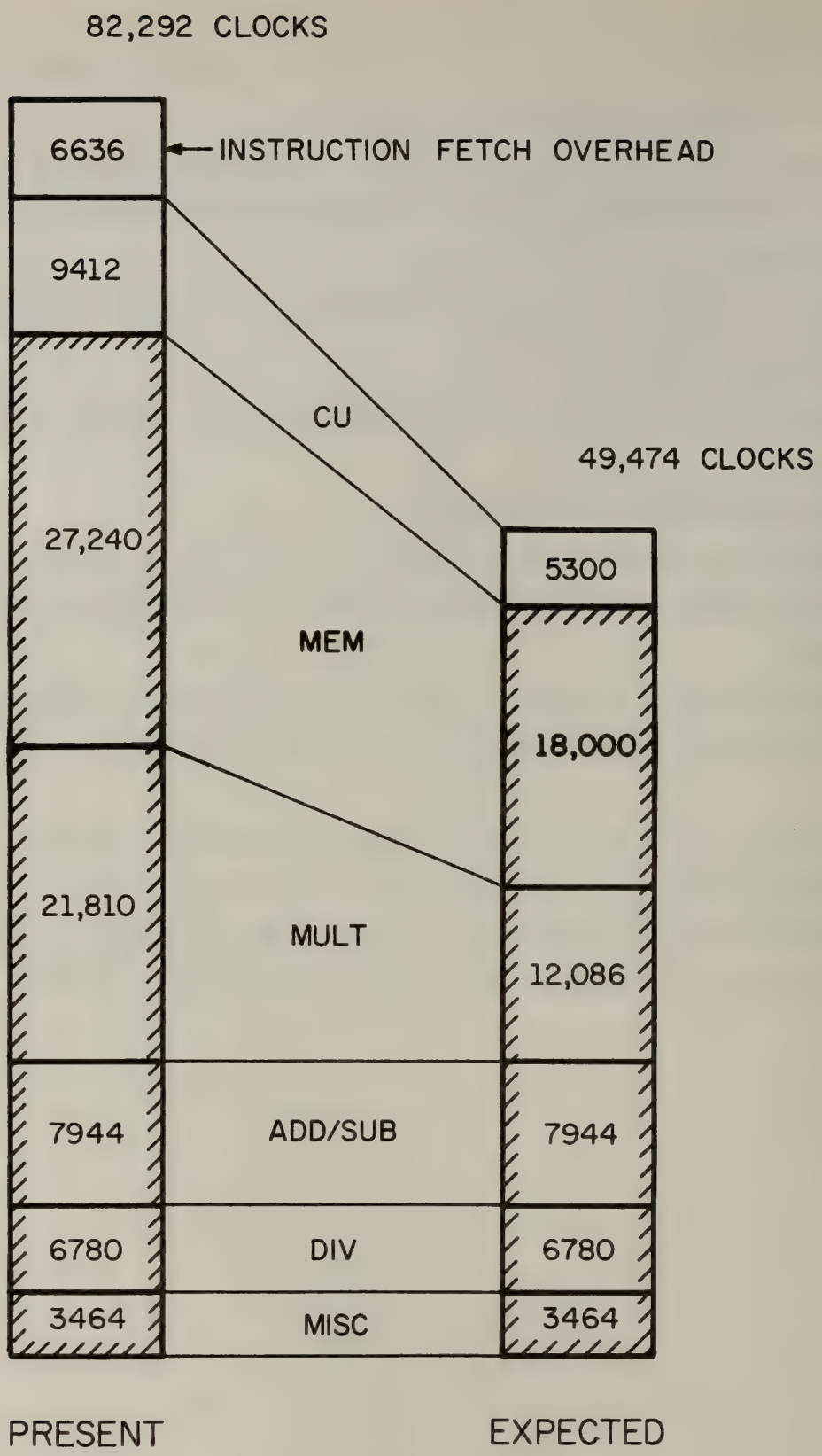


Figure 1. Dynamic Frequency of Operations in D-Type Code

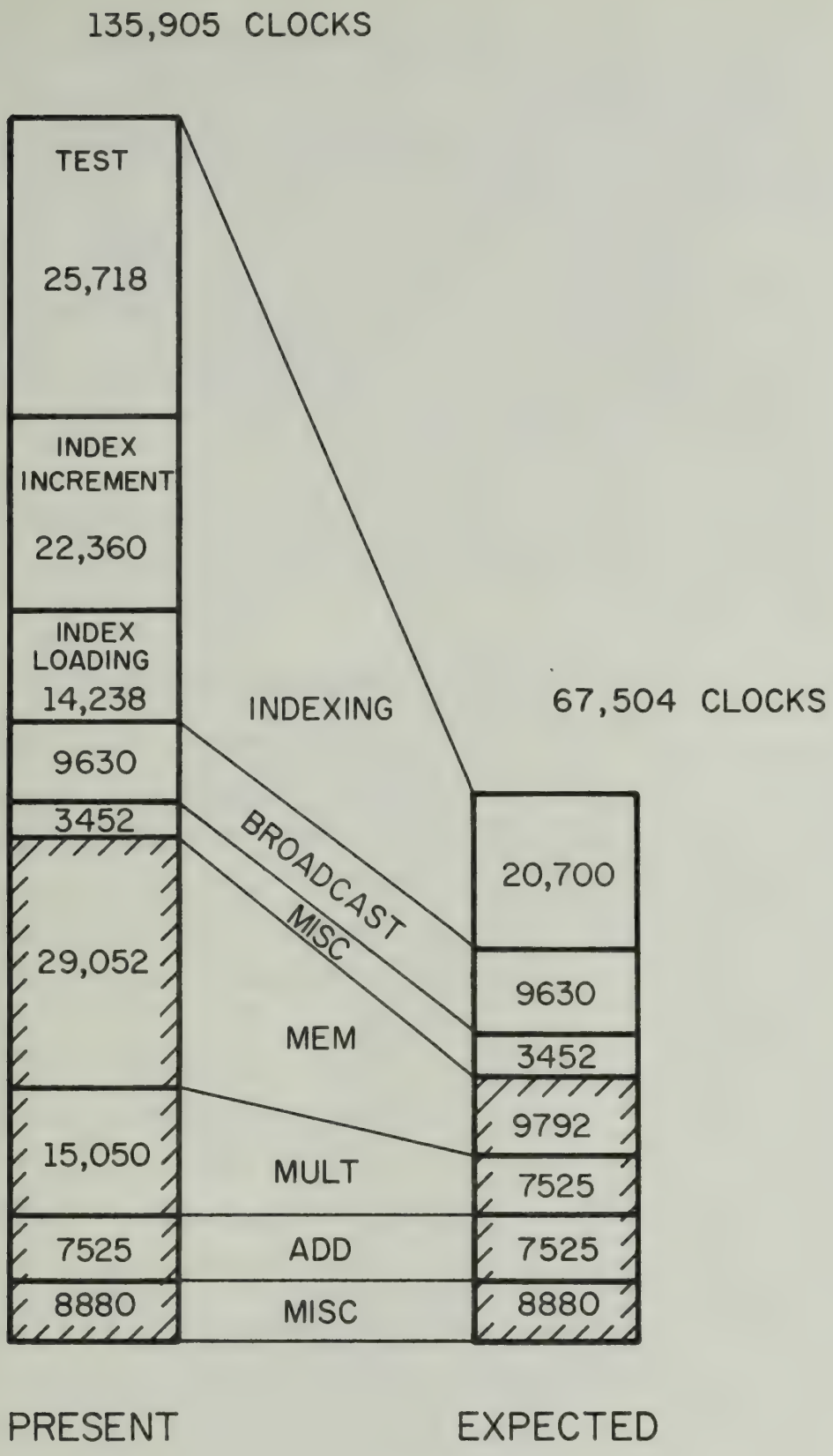


Figure 2. Dynamic Frequency of Operations in M-Type Code

4.2.3 Proposed Measures for Speed Improvement

4.2.3.1 Major Speed Factors

Major speed factors and possible logic schemes for further speed improvement are:

Factors	Schemes
Memory accesses	Memory-Arithmetic overlap
Multiplication	Simultaneous two 32-bit multiplication
Indexing	Index logic
Instruction fetch overhead	

The present proportion of each factor to the total execution time and the expected reduced proportion are shown in Table 1.

Table 1. Expected ILLIAC IV Speed Improvement

	Difference Equation Type Code (present)		(expected)	Matrix Type Code (present)		(expected)
Instruction fetch	8%	→	4%	---		---
Central Instruction[1]	11%	→	6%	55%	→	25%
PE Instructions						
MEMORY	34%	→	22%	21%	→	7%
MULTIPLY[2]	25%	→	14%	11%	→	6%
ADD/SUB	9%		no change	6%		no change
MISC.	13%		no change	7%		no change
Total	100%	→	68%	100%	→	51%
Speed improvement factor	~ 1.4			~ 2.0		

---

[1] Only the CU instructions in which CU clock dominates are considered.

[2] This improvement is effective in 32-bit mode only.

4.2.3.2 Memory--Arithmetic Overlap

A detailed analysis of the codes showed that 40 percent of the memory access is in the D-type code and 60 percent in the M-type code, can be overlapped with arithmetic operation. Memory access need should be detected and executed at least two instructions in advance, since the arithmetic instruction is often followed by an interregister transfer and/or routing instruction before the next memory access is made.

Figure 3 shows an example of a timing chart for the memory overlap in the M-type code. The function of memory access control will include:

a. memory access decoding
b. central indexing
c. address broadcast
d. local indexing
e. memory and register busy control.

Figure 4 shows elements involved in the memory access control.

4.2.3.3 Simultaneous Two 32-Bit Multiplication

The present two 32-bit multiplication algorithm, which repeats the multiplication for two pairs of operands, was described to take 12-clocks. A factor of two speed-up can be expected by doing the multiplication simultaneously for the two pairs of operands.

Figure 5 shows a logic scheme for suitable carry and multiplicand truncation to accomplish this, designed to have the least amount of effect on the regularity of the logic array.

The logic scheme requires 13 extra packages for extra logic blocks (hatched) as shown in Table 2 and modified packages for carry and multiplicand selection as shown in Table 3. However, the package modification introduces one extra gate delay which slows down adder tree cycle time.

The extra gate inputs to full adder shown in Figure 6 will eliminate this extra delay, which require chip design modification.

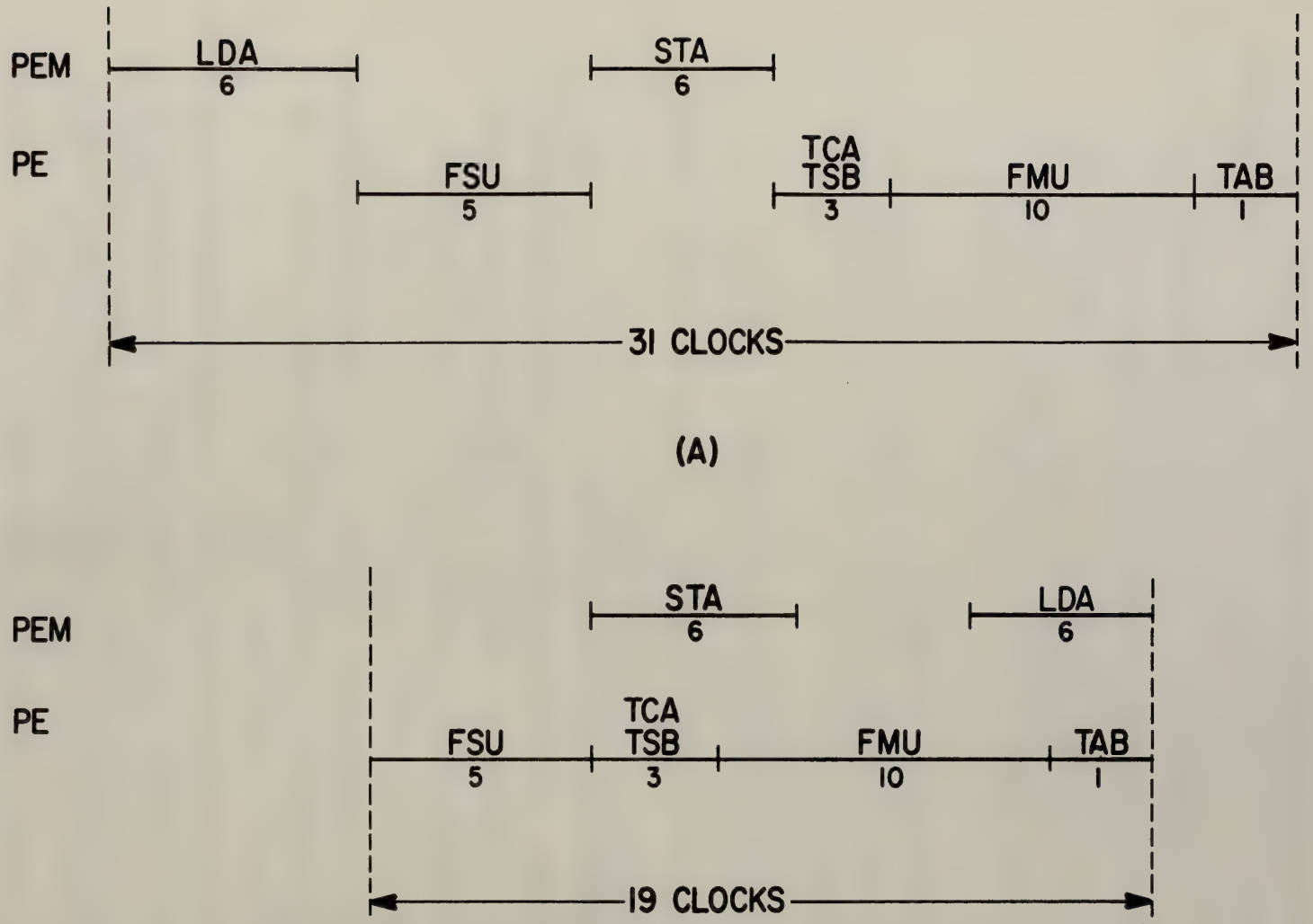


Figure 3. Memory and Arithmetic Operation Concurrency in a M-Type Code

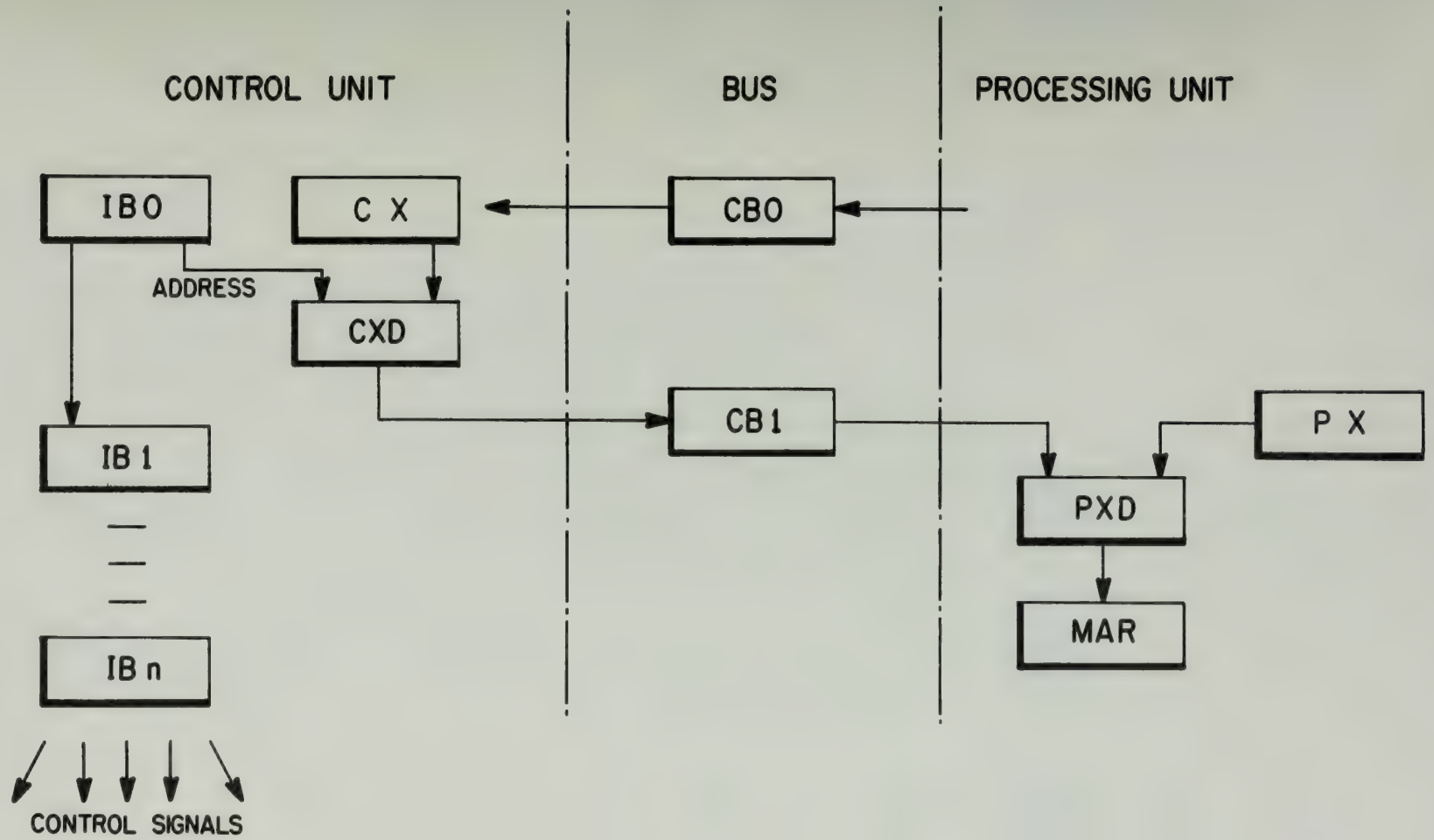


Figure 4. Memory Access Control

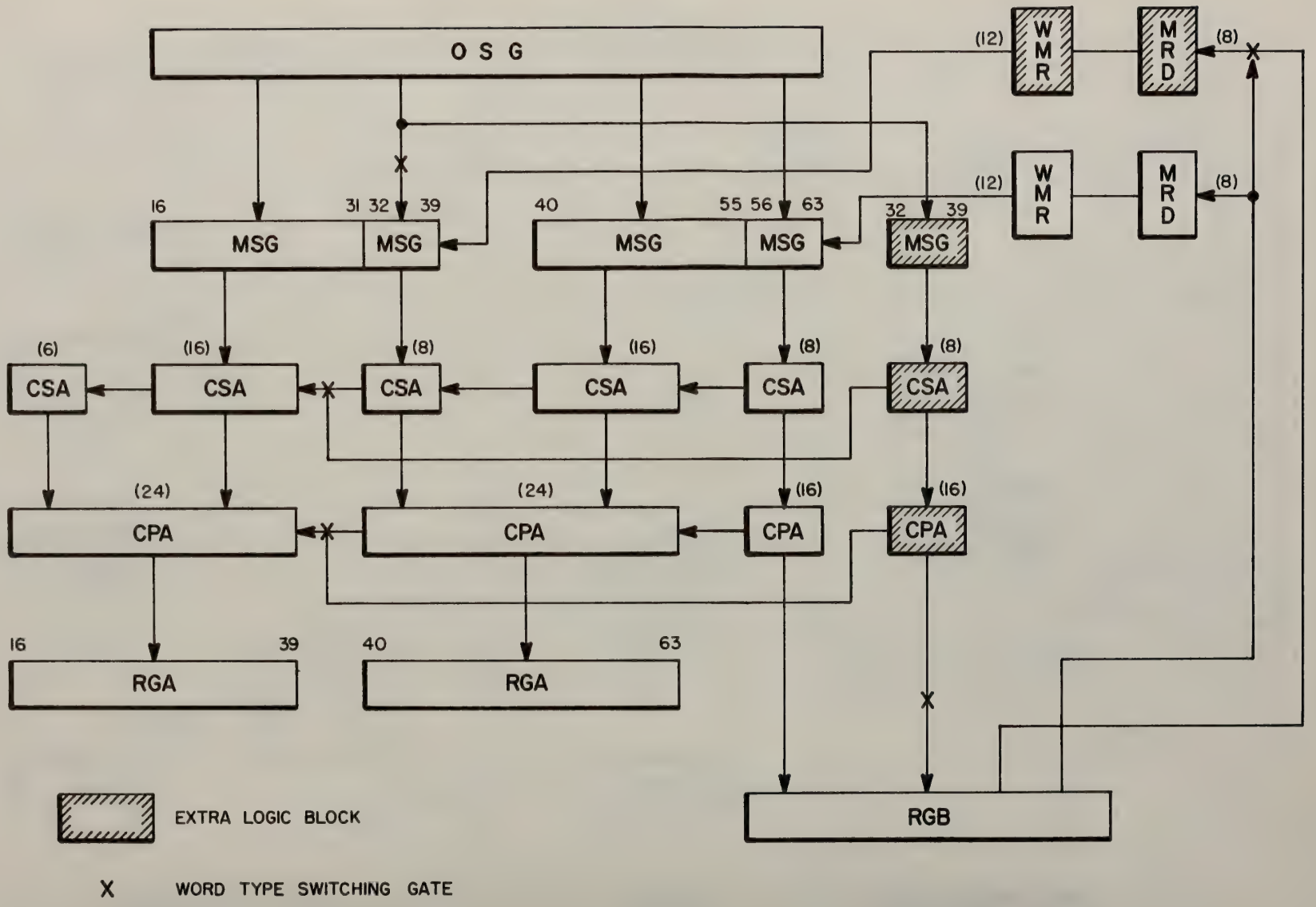


Figure 5. Extra Hardware for Two Simultaneous 32-Bit Multiplication

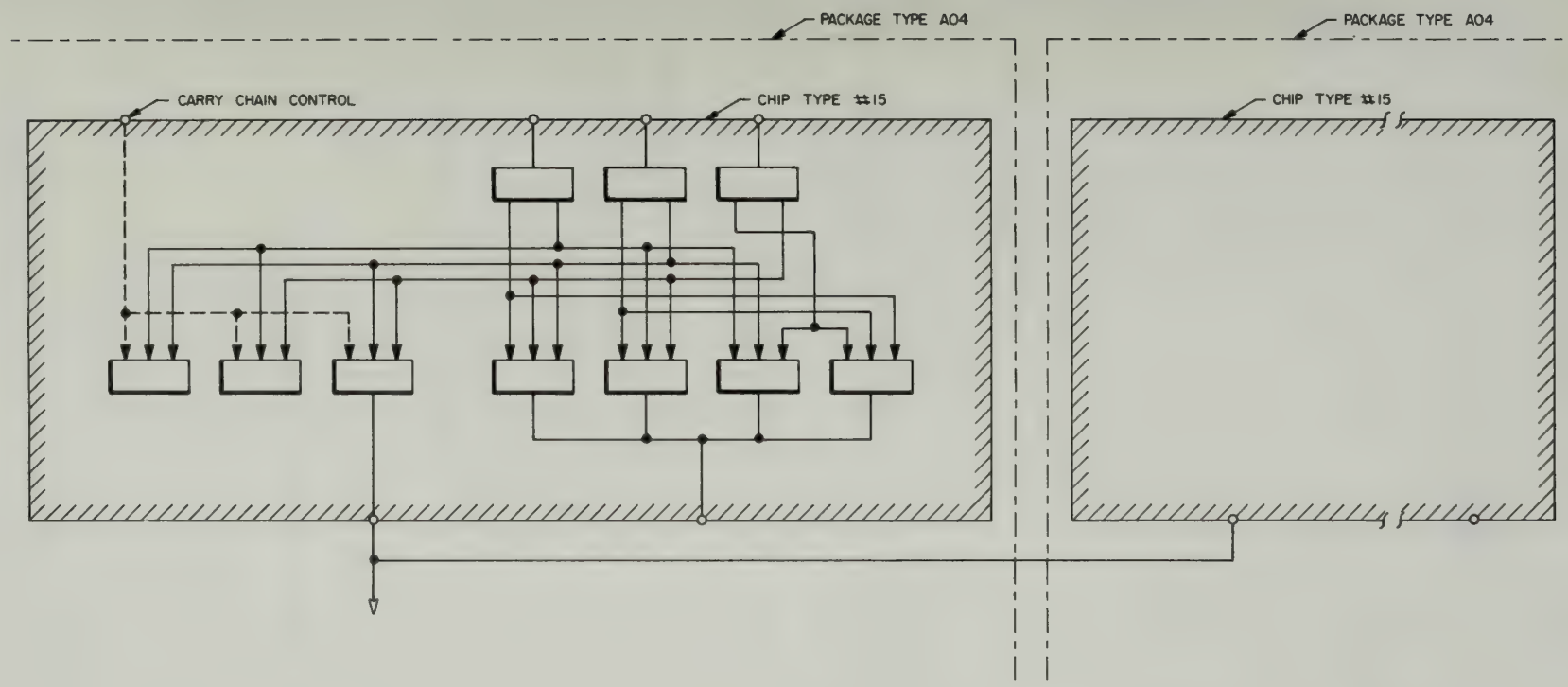


Figure 6. Carry Chain Control

Table 2. Extra Packages and Chips

Logic block	Package type[1]	Number of chips per package	Number of extra packages	Number of extra chips
MRD (8 bits)	A12	26	1	26
WMR (12 bits)	A02	10	2	20
MSG (8 bits)	A04	6	4	24
CSA (8 bits)	A05	21	4	84
CPA (16 bits)	A11	17	2	34
Total			13 packages	188 chips

[1] Package and chip types are based on those proposed in "ILLIAC IV SYSTEM STUDY FINAL REPORT" by Burroughs Corporation published in December 1966.

Table 3. Package Modification

Package Types	A03 A03A	A04 A04A
Number of chips package	9(45 gates)	12(120 gates)
Chip Types	#6 and #7	#14
Extra number of chips package	2(10 gates)	2(4 gates)
Type of extra chips	#7	#1
Required number of the modified package PE	1	1
Required number of the unmodified package[1] PE	15	15

[1] The modified packages can be used instead when less number of package types are desired.

4.2.3.4 Indexing Operation

The indexing is found to dominate in the computation time of the M-type code. This is because frequent indexing is required for counting rows, columns and partitions of matrices as well as counting elements to be broadcasted, whereas very simple arithmetic operations, mostly a multiply and an add, are involved in matrix operations.

For this reason it is suggested that enough hardware be provided to speed up incrementing and testing index values. Figure 7 shows logic elements concerned in the indexing. Transfer time is determined by total delay to travel around bold lines in Figure 7.

4.2.3.5 Instruction Loading

The presently proposed scheme for instruction loading requires 8 word blocks to be fetched one at a time from memory and sent to a buffer, called CUB, and then to be transferred into instruction buffer in the central control unit a word at a time. The instruction loading time is estimated to take 22 clocks which include 6 clocks to fill the CUB and 16 clocks to empty the CUB.

Since it is also proposed to use the CUB for address broadcasting, all the instructions with addressing feature cannot be executed during the instruction loading. In order to reduce this execution interruption, parallel transfer of words from the CUB into the instruction buffer or another CUB for address and data broadcasting is suggested as shown in Figure 8. The memory use for instruction loading, which amounts to 6.5 percent of the computation time in the D-type code, will cost no overhead if suitable buffering is achieved, since the memory still has 45 percent idle time even if all the speed-up schemes proposed here work as expected.

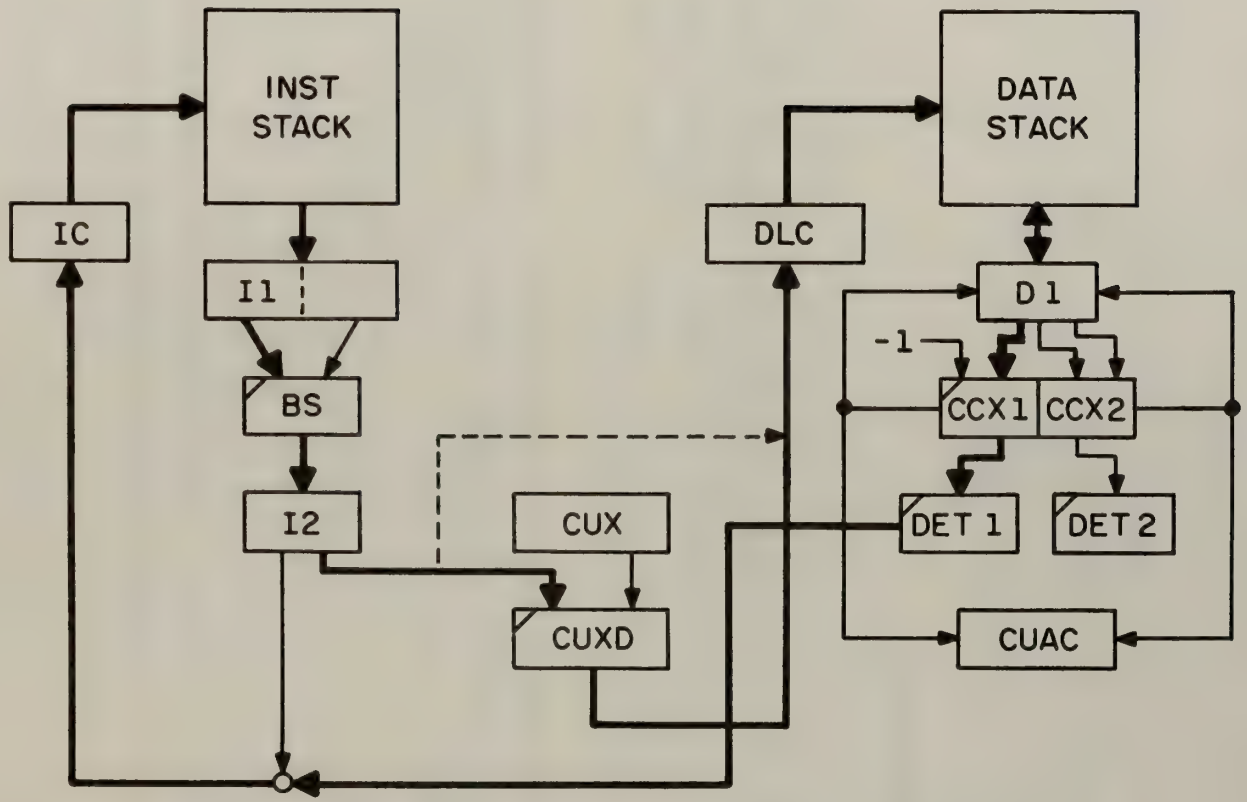
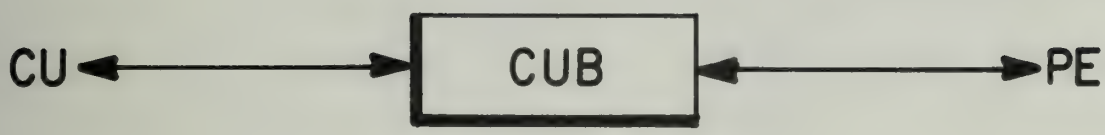
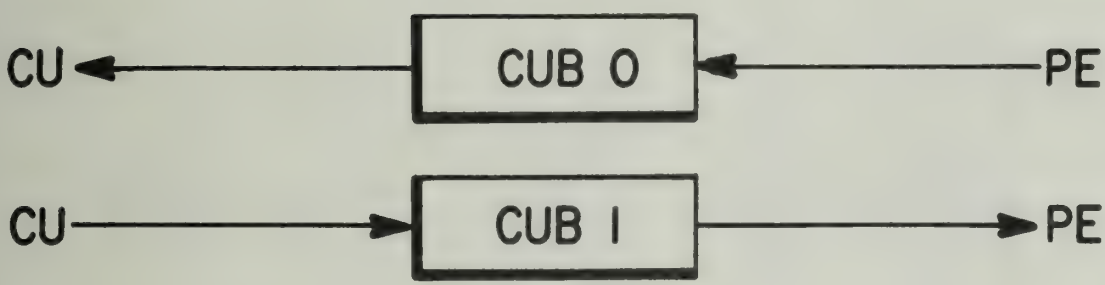


Figure 7. Index Adders and Index Adder Loop in Central Control Unit



a) common buffer for both directions



b) separate buffers for each direction

Figure 8. CU-PE Communication

4.2.4 Control Structure Modifications

In conclusion, at least three control circuits--indexing, operand accessing and execution--and a buffer are required for sufficient amount of concurrency to get the expected speed-up discussed so far.

Figure 9 shows such a four level control structure which allows the three controls to operate concurrently with a certain amount of interaction among them.

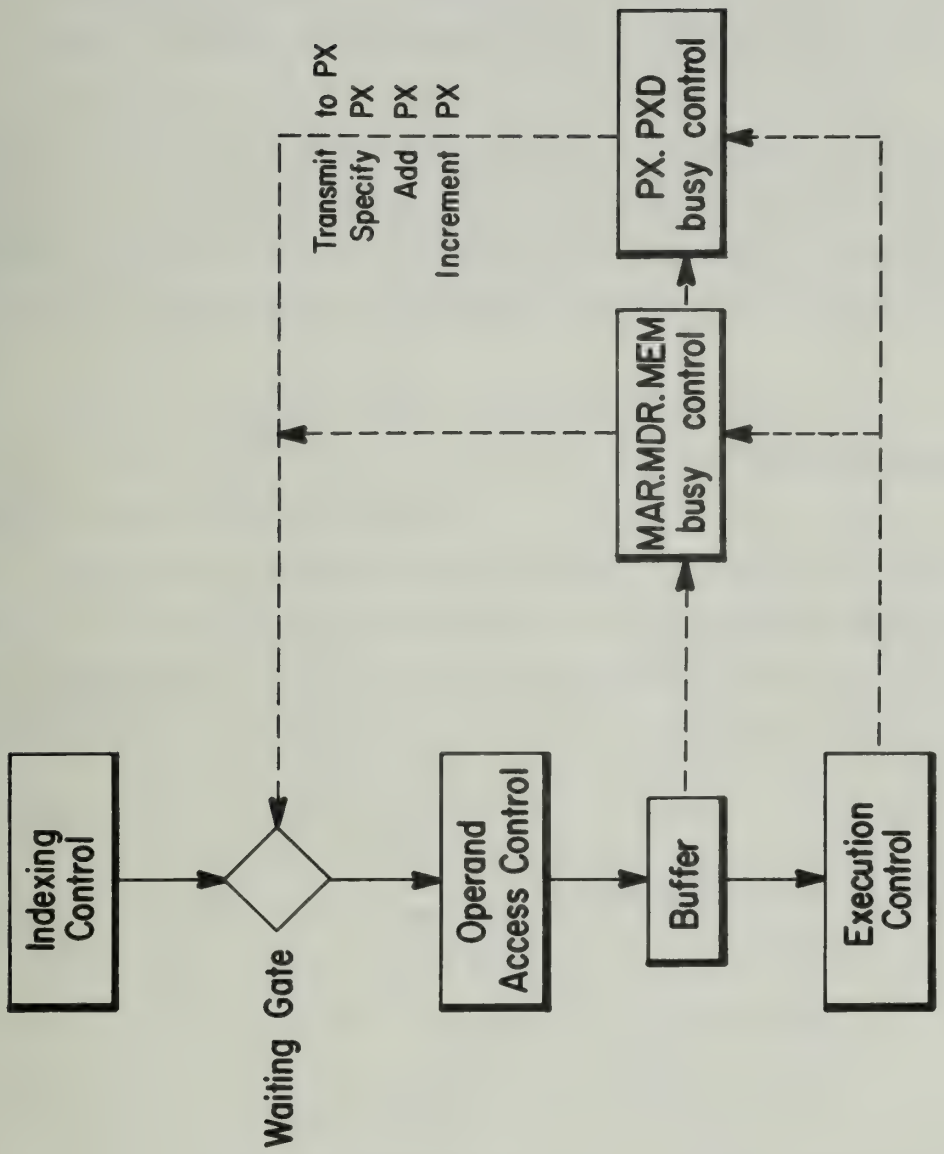


Figure 9. Four Level Control Structure

4.3 Applications and Software

ILLIAC IV applications activities are continuing to influence the software, as well as hardware organization. Half a dozen codes are continually updated according to the latest hardware ideas. Significance arithmetic, double precision and double length accumulation have been considered. The 32 bit length has been given attention, since only 64 bit words can be addressed.

Software activities have included simulation coding and high level language design. No ILLIAC IV language is planned, but rather a mixture of assembly language and array arithmetic statements will be used. A syntax directed translator will allow users to define new operations or use only old ones.

4.3.1 Signal Processing

The signal processing group is continuing studies relevant to the LASA data processing problem. During the last quarter considerable progress has been made toward a theoretical understanding of both Wiener and Maximum Likelihood Filtering. Following some interaction with Lincoln Laboratory attention has shifted to Maximum Likelihood processing, and it has been ascertained that ILLIAC IV can synthesize Maximum Likelihood Filters, both in the frequency and time domains, in an almost fully parallel manner.

Typical Results (64-bit precision)

(a) Time-Series Cross-Correlation:

20 subarrays, 25 channels/subarray
21 time lags, 1800 samples
computing time: ~ 2 seconds

(b) Maximum Likelihood Time - Domain Synthesis (Robinson Algorithm):

20 subarrays, 25 channels/subarray
21 point length
Computing time: ~ 2 seconds

4.3.2 Partial Differential Equations

The study of hydrodynamic calculations along the lines described in earlier reports is continuing. The two dimensional Eulerian code has been revised to include a consideration of the "table-look-up-problem" in connection with the equation of state. A LaGrangian Fortran code has been completed and an ILLIAC IV assembly language version has been undertaken.

The investigation of nuclear reactor calculations continues and a discussion of the numerical solution of the steady state multi-group transport problem by Carlson's discrete S_n method appears later in this report. It has been decided to treat the simpler steady state calculation before attempting further analysis of the time dependent case described in the last report.

The study of ADI methods emphasizing for the time being techniques for limiting the amount of working storage required is continuing and will be reported on in subsequent reports.

The study of "fast" methods for the solution of Poisson's Equation using Fourier analysis--methods which have their principal application in solving engineering problems concerning plasmas, electron tubes, and ion devices has begun. Two methods of this type have been considered: The first due to R. W. Hockney[1] reduces the Poisson Equation to a set of ordinary differential equations by means of Fourier analysis in one dimension. The set-up of ordinary differential equations is then integrated by the use of finite difference techniques. The second due to Mr. A. Hyman[2] is a double Fourier analysis and an interpolation from the boundary points to give the function values at the mesh point. Both methods are described later in this report.

4.3.2.1 Fourier Analysis - Hockney

In many engineering problems concerned with the design and study of electron devices, it is necessary to follow the motion of a large number of interacting changed particles. The interaction is treated in two dimensions and assumed electrostatic. The region of interest is subdivided by a regular grid of coordinate lines and the velocity and position of the particles tabulated. The particles are considered as fixed instantaneously

and the charge of each particle is associated with the center of the grid square containing it. The charge distribution thus obtained is used as the source term in Poisson's equation which, with suitable boundary conditions, may be solved for the potential distribution. Having the potential distribution it is then possible to calculate the forces on the particles. The particles are now considered to be free to move and are acted upon by the forces computed; the resulting accelerations alter the velocities and positions which at the end of some predetermined time step Δt are again fixed, and tabulated. The process is repeated for the next time step and so on.

The solution of Poisson's equation is carried out in the following manner:

$$\frac{\partial^2 \varphi}{\partial x^2} + \frac{\partial^2 \varphi}{\partial y^2} = \rho(x,y) \qquad \varphi = \varphi(x,y)$$

$$0 \leq x \leq \ell$$

$$0 \leq y \leq m$$

$$\varphi(x,y) = 0 \quad \text{for } x = 0,\ell \qquad y = 0,m.$$

If

$$\ell \leq m$$

we set

$$\varphi(x,y) = \sum_K \bar{\varphi}^{(K)}(y) \sin \frac{K\pi x}{\ell}$$

$$\rho(x,y) = \sum_K \bar{\rho}^{(K)}(y) \sin \frac{K\pi x}{\ell}$$

(If $\ell > m$ an analysis in the y direction is used.)

where $\varphi^{(K)}$ is the amplitude of the K^{th} harmonic.

Substituting in Poisson's equation and making use of the orthogonality of the sine functions, one obtains:

$$\frac{d^2\bar{\varphi}^{(K)}}{dy^2} + \left(\frac{K}{K}\right)\bar{\varphi}^{(K)}(y) = \bar{\rho}^{(K)}(y),$$

a set of K ordinary differential equations. It is possible to limit K, the number of harmonics present, to the value M -- the number of mesh points in the y direction. The usual finite difference approximation yields a tri-diagonal system of equations which we solve.

To recapitulate:

1) A Fourier analysis of the change distribution is made

$$\rho(x,y) \rightarrow \rho^{(K)}(y)$$

2) The K independent ordinary differential equations or the corresponding tridiagonal matrix equations is solved,

$$\bar{\rho}^{(K)}_{(y)} \rightarrow \bar{\varphi}^{(K)}(y).$$

3) The potential distribution is synthesized by means of Fourier methods

$$\bar{\varphi}^{(K)}(y) \rightarrow \varphi(x,y).$$

For certain special, though important, boundary conditions and coordinate geometries and by choosing the number of mesh points properly, one is able to employ several devices to reduce the number of operations necessary to accomplish the program outlined above to make the method competitive with others not employing Fourier methods.

For comparison the following table is reproduced from Hockney's paper (where one will find also a complete description of the calculation procedure).

Number of Operatives

SOR	Tensor Product	ADI	Fourier
$14N^3 \log N$	$4N^3$	$40\ N^2 \log^2 N$	$N^3/18 + 15.5N^2$

The above is for an n × n mesh. Hockney concludes that Fourier methods for the cases discussed are superior for $n < 10000$.

Programming the method for ILLIAC IV has only begun and a discussion of mesh point mapping and routing will be postponed for subsequent reports.

4.3.2.2 Fourier Analysis - Hyman

Another method which uses Fourier techniques to provide a direct solution to Poisson's equation is given by M. A. Hyman[2]. The method appears to be useful for a variety of regions and is executed in approximately $15\ N^2 \log N$ operations (N is the size of a "scaffolding" square which overlays the region).

For the present, attention is restricted to the Dirichlet Problem for a circular region (Figure 10.).

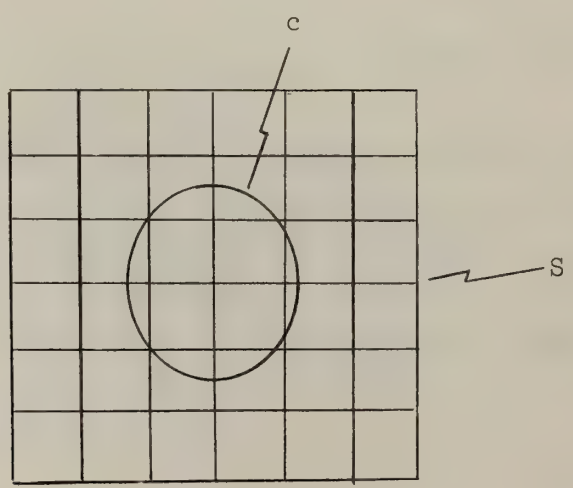


Figure 10. c_i = one of 2N points lying on the circle.

In brief, the method consists of:

Step 1 Solving Poisson's equation within the square region to obtain $\varphi_1(x,y)$ with the requirement that $\varphi_1(x,y)$ vanish on the square S;

Step 2 Interpolating $\varphi_1(x,y)$ to the circle, c, to obtain $\varphi_1(c_i)$, $i = 1,2, \ldots, 2N$;

Step 3 Solving LaPlace's equation within the circular region to obtain $\varphi_2(x,y)$ with the requirement that $\varphi_2(c_i) = \varphi(c_i)$, where $\varphi(c_i)$ are the boundary values of the original problem.

The desired solution is $\varphi(x,y) = \varphi_1(x,y) + \varphi_2(x,y)$ since it satisfies Poisson's equation within the circular region and takes on the given boundary values.

The Fourier representations are the most time-consuming portion of the process. They occur as follows:

Step 1 2 double Fourier representations

Step 3 N single Fourier representations

Using 3N log N operations as an estimate of the time to perform the Tukey-Cooley algorithm leads to the value 15 N^2 log N operations to execute Hyman's method. It is envisaged here that the side of the mesh square is a power of 2 in which case the method will be executed at nearly 100 percent efficiency if N is a multiple of 64. Further details may be found in an internal document of G. M. Ackins[3].

4.3.2.3 Carlson's S_n Method[4]

The numerical solution of the steady-state multigroup neutron transport equation by Carlson's discrete S_n method was studied assuming an isotropic medium.

In spherical geometry for a given energy group g the transport equation is

$$\mu \frac{\partial}{\partial r} \varphi^g(r,\mu) + \frac{1}{r}(1-\mu^2) \frac{\partial}{\partial \mu} \varphi^g(r,\mu) + \sigma_t \varphi^g(r,\mu) = S^g(r). \qquad (1)$$

Here φ is the neutron flux, σ_t the total cross-section for the loss of neutrons, μ the cosine of the angle between the neutron direction and the radius variable r, and S the source term.

A set of cells $C_{n,j}$ is formed by representing the radial variable r, and the direction cosine μ discretely. The interval $-1 < \mu < 1$ is divided into an even number of segments of equal width

$$\Delta_n = \mu_n - \mu_{n-1}, \quad n = 1,2, \ldots, N.$$

The interval $0 \leq r \leq R$ may be divided into equal segments or may be chosen arbitrarily. Here

$$\Delta_j = r_j - r_{j-1}, \quad j = 1,2, \ldots, J.$$

Considering the average directional flux $\bar{\varphi}_{n,j}$ in the cell $C_{n,j} = \Delta_n \Delta_j$ by assuming the flux is linear in both r and μ directions, $\bar{\varphi}_{n,j}$ may be expressed as

$$\bar{\varphi}_{n,j} = \frac{\varphi_{n,j} + \varphi_{n,j-1} + \varphi_{n-1,j} + \varphi_{n-1,j-1}}{4}$$

where the group index is omitted since it applies to all groups.

Basically, the discrete S_n method expresses $\bar{\varphi}_{n,j}$ in terms of the average values of the directional flux at the midpoints

$$\bar{r}_j = \frac{r_j + r_{j-1}}{2}$$

and

$$\bar{\mu}_n = \frac{\mu_n + \mu_{n-1}}{2}.$$

After defining

$$\varphi_n = \frac{\varphi_{n,j}+\varphi_{n,j-1}}{2}, \qquad \varphi_j = \frac{\varphi_{n,j}+\varphi_{n-1,j}}{2}$$

the average flux over the cell $\Delta_n \Delta_j$ is

$$\bar{\varphi}_{n,j} = \frac{\varphi_n+\varphi_{n-1}}{2} = \frac{\varphi_j+\varphi_{j-1}}{2} .$$

See Figure 10. By integrating the transport equation over the cell $\Delta_n \Delta_j$, treating each term separately, the first term of equation (1) becomes

$$\int_{\mu_{n-1}}^{\mu_n} d\mu \int_{r_{j-1}}^{r_j} \mu \frac{d}{dr} \varphi(r,\mu) dr = \Delta_n \bar{\mu}_n [\varphi_j - \varphi_{j-1}] .$$

Assuming $\varphi(r_j,\mu) = \varphi(r_j,\bar{\mu}_n)$ and using the trapezoidal approximation

$$\int_{\mu_{n-1}}^{\mu_n} \mu d\mu = \frac{\mu_n+\mu_{n-1}}{2} \Delta_n = \bar{\mu}_n \Delta_n .$$

The second term of equation (1) becomes

$$\int_{r_{j-1}}^{r_j} \int_{\mu_{n-1}}^{\mu_n} \frac{1-\mu^2}{r} \frac{d}{d_\mu} \varphi(r,\mu) d_\mu = \Delta_j b_n \frac{1}{\langle r_j \rangle} [\varphi_n - \varphi_{n-1}]$$

where b_n is the average of the quantity $1-\mu^2$ which is determined to be equal to $-\Delta_n(\bar{\mu}_n + \bar{\mu}_{n-1})$ from a neutron balance condition. The quantity $\langle r_j \rangle$ is the average radius and is usually approximated by

$$\langle r_j \rangle = \frac{2(r_j^3 - r_{j-1}^3)}{3(r_j^2 - r_{j-1}^2)} .$$

The removal term, the third term of equation (1), is

$$\int_{\mu_{n-1}}^{\mu_n} d\mu \int_{r_{j-1}}^{r_j} \sigma(r)\varphi(r,\mu)dr = \Delta_n \Delta_j \sigma_j \frac{\varphi_j + \varphi_{j-1}}{2} ,$$

again using a trapezoidal approximation and denoting σ_j as the midpoint value of $\sigma(r)$.

Finally, the last term of equation (1) (the source term) reduces to

$$\int_{\mu_{n-1}}^{\mu_n} d\mu \int_{r_{j-1}}^{r_j} S(r)dr = \Delta_n \Delta_j S_j$$

where S_j is the midpoint value of $S(r)$.

Collecting terms and noting that

$$\varphi_n = \varphi_j + \varphi_{j-1} - \varphi_{n-1} ,$$

the difference equation becomes

$$(\bar{\mu}_n + \frac{b_n}{\Delta_n} \frac{\Delta_j}{\langle r_j \rangle} + \frac{\sigma_j \Delta_j}{2}) \varphi_j + (-\bar{\mu}_n + \frac{b_n}{\Delta_n} \frac{\Delta_j}{\langle r_j \rangle} + \frac{\sigma_j \Delta_j}{2}) \varphi_{j-1} = \Delta_j S_j + 2 \frac{b_n}{\Delta_n} \frac{\Delta_j}{\langle r_j \rangle} \varphi_{n-1}$$

which is a three-point difference scheme[6].

The values $\varphi_J(\bar{\mu}_n)$ for $n \leq N/2$ denote the neutron flux incident on the external boundary. (For a vacuum boundary $\varphi_J(\bar{\mu}_n) = 0$, $n \leq N/2$.) At the center the directional fluxes are continuous, that is, for $j = 0$

$$\varphi_0(\bar{\mu}_n) = \varphi_0(\bar{\mu}_{N-n}), \quad 0 < n < N/2 .$$

The three-point difference scheme applies for values $1 \leq j \leq J$ and $1 < n < N$. For $n = 0$, $\bar{\mu}_n = -1$ and $b_n = 0$ and it is possible to start a recursive solution for the φ_j's, solving for φ_{j-1} if $\bar{\mu}_n$ is negative and for φ_j if $\bar{\mu}_n$ is positive.

Before solving for the angular flux recursively, the coefficients for the desired groups and $\Delta_n\Delta_j$ cells for each group are computed. To estimate the source an initial approximation of the scalar flux in each group is made.

The recursive solution is then started at $j = J$ along the line $\bar{\mu}_0 = -1$ where the boundary condition $\varphi_J(\bar{\mu}_0)$ is assumed to be known. Thus φ_{J-1}, φ_{J-2}, $\cdots$, φ_0 may be evaluated in turn. The lines $\bar{\mu}_1$, $\bar{\mu}_2$, $\cdots$, $\bar{\mu}_{N/2}$ are computed successively. The values of φ_n are determined by linear interpolation:

$$\varphi_n = \frac{\varphi_{j-1}(\bar{\mu}_n) + \varphi_j(\bar{\mu}_{n+1})}{2} .$$

For the lines $\bar{\mu}_n$, when $n > N/2$, the direction of integration is reversed and

$$\varphi_n = \frac{\varphi_{j-1}(\bar{\mu}_{n+1}) + \varphi_j(\bar{\mu}_n)}{2} .$$

The integration is thus performed in the direction of neutron motion, a procedure which reduces the truncation error of the difference scheme. (See Figure 12.)

After all $\bar{\mu}_n$ levels have been evaluated the source term is recomputed from the latest figures available by a simple average of the φ_n's over the N $\bar{\mu}_n$ levels. Explicitly,

$$S_j = \frac{1}{N} \sum_{n=0}^{N} A_{n,j} \varphi_n$$

where the matrix $A_{n,j}$ represents the scattering and fission processes averaged over the interval j-1 to j.

After a group has been considered once, another pass through the same group may be made or the calculation may continue on to the next group. A pass through all the groups is called an outer iteration. Repeated solutions for a particular group are called inner-iterations.

For criticality studies, there is no external source. In this case, the fission and scattering terms of the same group in the source function is divided by a criticality coefficient λ, which is initially estimated. The eigenvalue λ is reevaluated after each outer iteration, and the process is terminated when some convergence criterion on λ has been satisfied.

Details of the method can be found in the list of references on page 38.

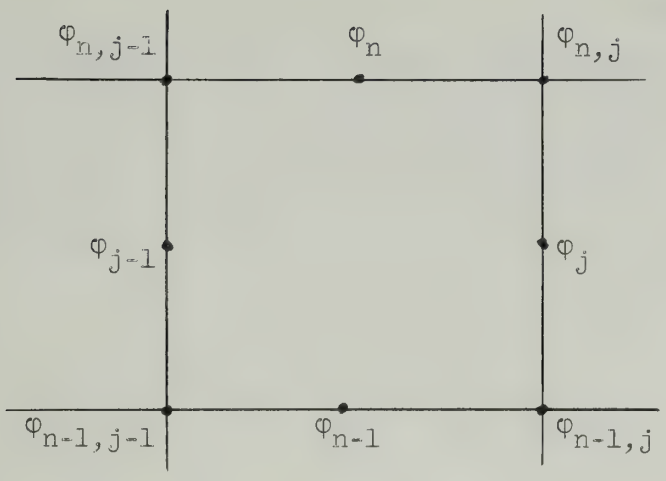


Figure 11.

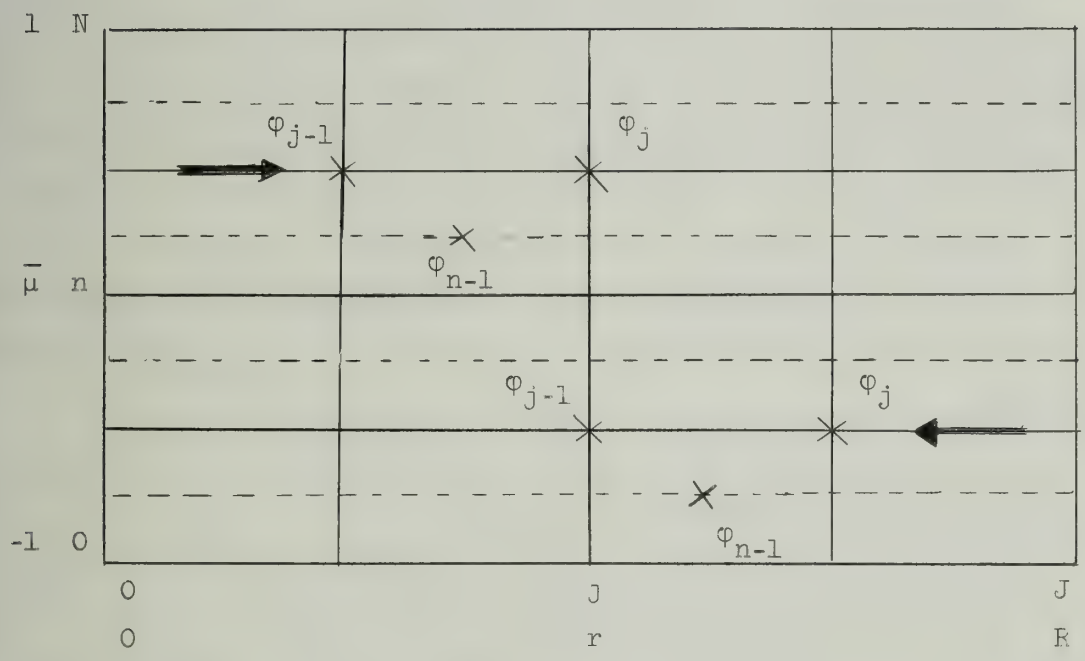


Figure 12.

4.3.3 Meteorology

Most of the weather effort in the last quarter was devoted to supporting machine and language development. Since the appearance of the first ILLIAC IV version of the NCAR general circulation model, it has been recoded in each of the several new versions of machine language; such attention not only maintains the circulation model, but also helps point up shortcomings in the machine language.

Since it is evident that a high-speed computational ability is useful for meteorological purposes other than large-scale atmospheric modeling, ILLIAC IV now has the services of Dr. Eberhart Wahl of the University of Wisconsin, Department of Meteorology; he will help to develop ILLIAC IV as a more general meteorological tool.

4.3.4 Linear Programming

Developments on the linear programming effort have been directed to education and training of the student assistants. This is necessary at this time since the machine definition is still forthcoming. Most of the work has been in consideration of internal processing sequences using the December 15 version of the machine. The lack of disk input/output definition prevents more than exploratory probes into the structure of the product form code. However, it has been determined that disk latency can be masked if the input/output buffer is sufficiently large, i.e., one disk revolution plus one sector number of bits.

4.3.5 ILLIAC IV Simulator System

A fairly complete description of the ILLIAC IV Simulator System appears in the Second and Third Quarterly Progress Reports. Hence, most of the following merely reports progress (or setbacks) along technical lines previously described. The single new item discussed is the System Monitor Program.

The System Monitor is one of three core-loads (the Assembler and Machine Simulator are the other two) which comprise the Simulator System. The core-loads are "ping-ponged" in and out of 7094 core in order to simulate a "load and go" batch processor. The most important duties of the Monitor are clearing the registers and memory of the simulated machine and loading programs to the pseudo PEM. In addition, this program handles exceptional conditions, terminal dumps, user statistics, etc.

The executive control portion of the machine simulator has been designed and coded. A large part of this program actually represents simulation of the CU's, and therefore, refinements must be made as the CU design progresses.

With the adoption of the new 32-bit format for the ILLIAC IV instruction complement, approximately 25 percent of the instruction simulation portion of the Machine Simulator and nearly all of the Assembler must be recoded. Changes and/or additions were expected by internal program logic, within the syllabic micro-program framework established several months ago, but the latest nonsyllabic format has clearly abandoned that framework.

As the machine design fluctuates less and less in the next few months, there will be corresponding accelerations in progress of the Simulator System.

4.3.6 An ILLIAC IV Language

4.3.6.1 Introduction

A language for ILLIAC IV is in the initial stage of development. Its translator will allow the use of high level instructions such as the matrix operation C = A·B, intermediate level instructions such as

$$A(I,J) = B(I - 1, J + 1) + C(I - 2, J + 2)$$

for some I and J, assembly language instructions, and machine language instructions. The initial effort has been made largely from the perspective of the user with the idea that he should not have to be concerned about the way his data will be stored in memory; rather, that he should only have to view his problem in its mathematical description.

Several reports have been written with regard to possible translator statement; these fall into two categories: data structures and control statements.

4.3.6.2 Data Structures

A number of schemes have been developed for storing various types of data in the PE memories. In the higher level use of the translator, the user will not need to specify the allocation of his data in detail, but may choose from existing methods when they are available. He may alternatively allow the translator to decide for him, as may be the case if he is working with matrices. However, for structures that the translator is not capable of handling, means are provided that will allow the user to place his data in memory as he sees fit.

Although the user has the options just stated, it will be required that he make dimension statements for his data structures. These statements are to be dynamic in nature.

The user may also find it convenient to partition some of the data structures he has declared in order to refer to different segments of them. This will also be allowed.

Some examples will illustrate the three general areas of concern in dealing with data structures.

I. Dimension Statements

a. DIMENSION (V(N))

results in declaring N to be the dimension of V, where:

$$V = (V(1), \ldots, V(N))$$

b. DIMENSION (I)V(M), for I IN (1,2,3))

results in declaring 3M to be the dimension of V, where:

V = ((1)V, (2)V, (3)V)

(1) V = ((1)V(1), ..., (1)V(M))

(2) V = ((2)V(1), ..., (2)V(M))

(3) V = ((3)V(1), ..., (3)V(M))

such that

V(M + 5) = (2)V(5)

II. Assignment Statements

a. FOR M = 1, 10

FOR K = 1, 256

PE(I,J): = (M)AE(K),

where

I = M

J = M + K - 1 (mod 256)

$1 \leq J \leq 256$.

This statement serves to store the vector (M)AE in skewed fashion:

(word) I	1	2	. . .	256	
1	(1) AE(1)	(1) AE(2)	. . .	(1) AE(256)	(1) AE
2	(2) AE(256)	(2) AE(1)	. . .	(2) AE(255)	(2) AE
⋮	⋮	⋮	. . .	⋮	
10	(10) AE(248)	(10) AE(249)	. . .	(10) AE(247)	(10) AE

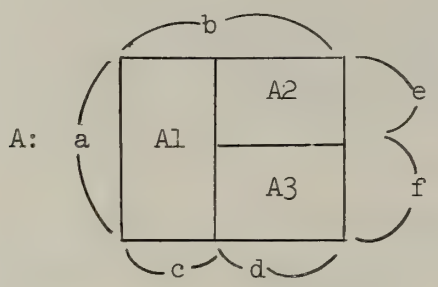
III. Partitioning Statements

a. MATRIX: A(a,b), A1(a,c), A2(e,d), A3(f,d)

(A1, (A2/A3)) = A,

where:

1. "," serves to show the parallel arrangement of matrices.
2. "/" serves to show the serial arrangement of matrices.
3. The figure is:



4.3.6.3 Control Statements

Since ILLIAC IV is a parallel machine, simultaneous control statements, as well as sequential control statements, are being developed. Those statements allow the use of more than one index set at a time in several ways.

Several illustrations of simultaneous control statements and the use of index sets follow after a definition of SIM.

$$\text{SIM } (S_1; \ldots; S_n)$$

means that $S_1, \ldots, S_n$ are all to be executed simultaneously, i.e., the data used by each S_i is to be the data available before any one of the S_i is executed. Thus, effects of S_i on the data structure are not noticed by S_j, for all $i \neq j$.

Example 1:

```
FOR I SIM (1, 2, 3, ..., n) DO
        A(I) = B(I);
```

means

```
SIM (A(1) = B(1); ...; A(n) = B(n))
```

which may involve routing and indexing.

Example 2:

```
FOR (I,I) SIM ((1, 3, 5, 7), (2, 4, 6, 8)) DO
        A(I) = B(I);
```

is executed as

```
SIM (A(1) = B(2)
     A(3) = B(4)
     A(5) = B(6)
     A(7) = B(8))
```

Example 3:

```
FOR (I, J) SIM (I * J) DO
BEGIN
  C(I, J) = 0;
  FOR K SEQ (1, ..., n) DO
  C(I, J) = C(I, J) + A(I, K) * B(K, J)
END
```

forms an array of dot products simultaneously, i.e., multiplies two matrices.

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5.1 Numerical Analysis

Further investigations were made of the newly developed sequential extrapolated implicit method (SEI) for the iterative solution of linear systems approximating elliptic partial differential equations.

In the case of an equation of the form

$$\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \sigma^2 u = f(x,y)$$

on a rectangular domain, there is a decomposition of a block operator in terms of the spectrum of the block matrix. As noted in a previous report, it is possible to choose a set of extrapolation factors $\{w_1, w_2, \ldots, w_n\}$ and a set of origin shifts $\{r_1, r_2, \ldots, r_n\}$ to produce an operator which anihilates the error in coordinate directions corresponding to each of two eigenvalues, α_1 and α_2 say, of the block matrix. The technique of using a different extrapolation factor and a different shift of origin for each block matrix is called the variable sequential extrapolated implicit method (VSEI).

It has recently been discovered that for fixed α_1 and α_2, there are several different pairs (Ω,R), where $\Omega = \{w_1, w_2, \ldots, w_n\}$ is a set of extrapolation factors and $R = \{r_1, r_2, \ldots, r_n\}$ is a set of origin shifts, such that the operator using (Ω,R) anihilates the error corresponding to α_1 and α_2. Numerical experiments have shown that these different pairs (Ω,R) are not equivalent in that when the rate of attenuation of error by an operator is plotted against an eigenvalue β of the block matrix, the curves for operators using different pairs (Ω,R) are not the same, although they all go through zero at $\beta = \alpha_1$ and $\beta = \alpha_2$. If $\rho(\beta)$ represents the rate of attenuation of error corresponding to an eigenvalue of the block matrix equal to β and if $\underline{\beta}$ and $\overline{\beta}$ are the spectral bounds of the block matrix (whose spectrum is known to be real), then an optimal pair (Ω,R) among all pairs which

anihilate the error corresponding to α_1 and α_2 is one such that

$$\max_{\underline{\beta} \leq \beta \leq \bar{\beta}} \rho(\beta)$$

is minimized. An effort is being made to discover analytic (i.e., nonexperimental) criteria for selecting such an optimal pair.

It has also been found by numerical experiments that SEI, which has been shown to have the same asymptotic rate of convergence as SOR for equations defined on rectangular domains, has a higher asymptotic rate of convergence for certain nonrectangular domains. Work is continuing in an effort to explain and extend these results.

(D.B. Gillies and L.K. McDowell)

5.2 Autonomous Arithmetic Unit Structures

The investigation of the implementation of division in the autonomous arithmetic structure was continued. An analog technique for performing the model division required to determine quotient digits was explored. A method was devised which requires one operational amplifier-comparator stage for each base two signed digit obtained during a model division, one additional operational amplifier-comparator and three summing operational amplifiers. Only two module types are required, making this scheme attractive for integrated circuit implementation. However, all but three of the amplifiers must re-stabilize sequentially, which is its major disadvantage. Manufacturers' literature on integrated circuit operational amplifiers indicate that slewing rates of 50 to 100 ns are possible with present devices. Since digital logic element propagation delays of 3 to 5 ns are also presently possible, the use of this method can be justified only if 20 or more propagation delays are required to execute one cycle of the division algorithm. Due to the nature of the autonomous arithmetic unit, i.e., the necessity of control circuitry distribution, a cycle of the division algorithm may indeed take that long.

(M.J. Pisterzi)

5.3 Theory of Arithmetic Unit Structure

The last quarter period was spent in completing research for and in writing up the results of a doctoral thesis. The thesis is concerned with adders having limited carry/borrow propagation for digital computers. It develops a systematic procedure for the determination of the algebraic (as opposed to logical) structure of such adders given the digit sets of input and output (sum/difference) operands, and presents the results of a study of some statistical aspects of a few selected adders. The thesis will be submitted as a final report for this phase of the contract during the second quarter of 1967.

(F. Rohatsch)

5.4 Algebraic Manipulation

The work during the last quarter mainly involved the continuation of the implementation and perfection of the list processing language IL5 (Illiac Low Level Linked List Language) to be used for testing the polynomial manipulation algorithms which are to be studied. The major contributions during this period have been a flexible I/O routine which allows easy switching of Input and Output lines to/from the batch tapes, the time share consoles and files on the disk via a file by name routine, a loader which is capable of loading and deleting procedures during the execution and an overlay routine which was necessitated to keep the small Illiac II core as free for data as possible. Minor changes to the assembler and interpreter which were previously written were also made.

As a list processing language, IL5 is particularly well suited for algebraic manipulation studies since it, as L^6, the language after which it was modeled, has most of the underlying features of other list processors such as IPL, LISP, SLIP and REFCO which have been used as languages for the implementation of manipulators. The dynamic storage allocation employed permits the use of various sizes of blocks whose length is 2**N words, where N ranges from 0 to 8 for the present version of IL5. The one extreme in which only blocks of single words

are used results in list structures similar to those of LISP. The other extreme in which the number of words in a block is made arbitrarily large results in a randomly addressable memory which is referenced by the "field" or index registers of IL5. This latter feature adds parallel access of data to the normally sequential access found in list processors. The capability of extracting and inserting arbitrary bit sequences in a word makes the language very convenient for the implementation of polynomial representations such as those used in ALPAK where a format specifies the context by which subfields are to be interpreted as components of a multivariate polynomial.

IL5 was written in the form of an interpreter simulating the fictitious IL5 machine rather than as a set of MACROS depending on a specific programming system for their capabilities. This decision results in a processor which is easier to describe formally, requires less core for programs, is easier to convert from one machine to another (at least for the author) and permits changes and additions in the language to be made easier. A definite disadvantage is the resulting decrease in speed, but this is a secondary consideration in the present set of circumstances.

The processor is divided into a number of subsections with distinct functions. The interpreter is the basic routine which scans a string of intermediate language characters which were generated by the assembler and linked for interpretation by the loader. This interpreter is the routine which accepts as input the program string and data from the I/O devices and changes the states of the registers in the IL5 machine according to its formal description. Conversion of IL5 to another machine requires that the interpreter be rewritten so that an intermediate language program string will produce a sequence of IL5 machine states identical to the sequence in the original computer.

The assembler accepts input lines containing descriptions of IL5 state changes, referred to as "actions", in a relatively primitive but convenient format and converts them into the compact left context sensitive intermediate language. A collection of such lines can be grouped to form an independent procedure which is output as a procedure deck into a file. The function of the loader is then to combine a number of these procedures into a program which is ready for execution.

The loader is capable of being called during execution making it possible to add or delete programs which consist of a set of procedures distinct from those in the initial program. This feature is possible because of the dynamic storage allocation in IL5 and aids in leaving the maximum amount of space free for use as data. A secondary result is that large programs with many procedures may be executed despite the small core.

(S.J. Nuspl)

5.5 Artificial Languages

During the last quarter, the following steps of the EOL project were performed.

(1) The language X1 for defining the EOL interpreter was defined and edited as a separate draft.

(2) The first version of the EOL interpreter in the X1 language was written.

(3) The EOL interpreter written in IBM 7094 code on the basis of (2) was advanced.

(4) The EOL language was extended in many respects to obtain more generality and internal consistency. The new EOL version is called EOL-3).

(5) Work on the EOL-3 translator was started.

(6) A few examples of EOL-programs were elaborated and described.

(L. Lukaszewicz, J. Nievergelt,
F. Fischer, D. Edgar, and
R. Sanders)

6. COMPUTATIONAL PHYSICS

The Monte Carlo Method in Quantum Statistics

Introduction

The amount of Monte Carlo work in the area of quantum statistical mechanics is quite small compared with that in classical statistical mechanics. Most of the Monte Carlo work in quantum statistical mechanics has used the Wiener integral to cast the computational problem into a form suitable for a Monte Carlo technique. An exception to this is the work of Handscomb on the Heisenberg model of a ferromagnet [1]. Since the Wiener integral is basic to most of this work it seems natural to begin with a description of it and of its connection with quantum statistics.

Let $x(\tau;n)$ be a piecewise straight line on the interval $(0,\beta)$ with breaks at $\tau_1,\tau_2,\ldots,\tau_{n-1}$, and with $\tau_0=0$, $\tau_n=\beta$. An example with $n=4$ is shown in Slide 1. Let $x(\tau)$ be a continuous function of τ on $(0,\beta)$, and $F[x(\tau)]$ a functional of $x(\tau)$, the the conditional Wiener integral, $E\{F|x(\beta) = X\}$, of F is defined by the equation in Slide 2. The adjective "conditional" is used to describe the fact that $x(\tau)$ is subject to the condition $x(\beta) = X$. The normalization condition, Eq. (4), establishes the value of A_n. Continuity of F, in the Hilbert topology, is sufficient to ensure the existence of the limit in Eq. (1). There are more sophisticated ways to define this integral, [2,3] however this way seems to require the least prior knowledge.

Notice that $d\mu_n$, Eq. (2), is a joint Gaussian probability. We may view the conditional Wiener integral as an average of the functional F, where the average is taken over all "paths" $x(\tau)$, with the property that $x(0) = 0$, $x(\beta) = X$ and the statistical weight of a path is three sets of paths of this type, corresponding to the three possible assignments of the numbers 1, 2, 3 to the paths.

Numerical Evaluation of the Wiener Integral

The usual approach to the problem of numerically evaluating a Wiener integral consists of two distinct steps: first, the Wiener integral is approximated by an n-fold Riemann integral; second, this n-fold Riemann integral is estimated by the Monte Carlo method. In rare instances it is possible to evaluate the n-fold Riemann integral directly by analytic methods, determine the limit as $n\to\infty$ of this result, and thus obtain an exact value for the Wiener integral.

(a) Approximation by an n-fold Riemann integral. The simplest way to approximate the Wiener integral by an n-fold Riemann integral is by truncating the limit process shown on the right of Eq. (1). This gives the approximation shown in Eq. (10) of Slide 5. In this equation $x(\tau;n)$ and $d\mu_n$ are as previously defined in Eqs. (2), (3) and (4). This is a special case of a more general approximation, the rectangle approximation of Cameron [7], in which the path is expanded in terms of a complete orthonormal set in the space of functions which are continuous on the interval $(0,\beta)$ with $x(0) = 0$, $x(\beta) = X$. The expansion coefficients are proportional to Gaussian random variables. For example, if the τ-interval is normalized to (0,1), then the path may be represented by Eq. (11), and using $d\mu_n$, defined in Eq. (12), in Eq. (10) we have another approximation of the same type. It can be shown that the error in this approximation is $\mathcal{O}(n^{-1})$. If this approximation is used to evaluate the partition function for a one dimensional harmonic oscillator, a case where all of the integrals can be calculated exactly, then the minimum value of n required for a given relative error ρ in the partition function is as shown in Slide 6. It will be observed that the numbers in this table exhibit, roughly, the $\mathcal{O}(n^{-1})$ behavior.

Other approximation formulas with an error term $\mathcal{O}(n^{-k})$, $k > 1$, have been developed for Wiener integrals. Cameron [7] has developed a "Simpson's rule" in which the error is $\mathcal{O}(n^{-2})$; the principal idea is the use of a one dimensional integral which will give the exact value of the Wiener integral for polynomial functionals of third degree. A class of approximation formulas, containing Cameron's as a special case, has been developed by Konheim and Miranker [8]. These formulas have been developed

for the Wiener integral (i.e. $x(\beta)$ not specified) rather than the conditional Wiener integral in which we are interested. It should be straightforward to adapt these formulas to the conditional Wiener integral but this has not been done. Fosdick [9] developed an approximation for conditional Wiener integrals of the functional shown in Eq. (15) of Slide 7; the principal formulas are shown in Eqs. (13) and (14). The error in this approximation is $\mathcal{O}(n^{-2})$. An illustration of the effect of this approximation is shown in Slide 8, where the error in the partition function for a quartic oscillator ($V(x) = x^4$) at $\beta = 1$ is shown as a function of n. In one computation represented by $\square$, Eq. (10) was used as the approximation and in the other computation represented by $\bullet$, Eq. (13) was used. In both cases $x(\tau;n)$ was the broken straight line representation for the path and $d\mu_n$ was given by Eq. (2). Here Monte Carlo sampling was used to evaluate the multidimensional Riemann integrals; 10,000 sample paths were used.

(b) Monte Carlo estimation of the multidimensional Riemann integrals. Each Monte Carlo sample is a path. The sampling process consists, therefore, in the generation of a path with the required statistical properties. Now it is important to recognize that it is not practical to do this by generating a random walk in which the steps are independent Gaussian random variables, because the constraint $x(\beta) = X$ would cause almost all paths to be discarded. There is a simple procedure for dealing with the constraint. Let us consider the set of paths which visit the points x_{i-1}, x_i, x_{i+1} at "times" $\tau_{i-1} < \tau_i < \tau_{i+1}$. The relative probability density for this set is given by Eq. (16) of Slide 9, where on the left the notation used is to emphasize the fact that we now want to regard x_i as a random variable conditional on x_{i-1} and x_{i+1}. From this it follows easily that Eq. (17) is an expression for the random variable x_i, given x_{i-1}, x_{i+1}. This is called the interpolation formula and we use it to generate the conditional Wiener paths. Thus the generation of a path $x(\tau;n)$ consists in the selection of n-1 Gaussian random variables and n-1 applications of the interpolation formula.

Computations on He^4

Using the ideas described above Harry F. Jordan and the author have made a number of computations on He^4; some of these have already been reported [10]. Equations relevant to the discussion of these computations are shown in Slide 10. The N-particle Slater sum is represented by W_N, Eq. (19). A Lennard-Jones 6-12 potential has been used, Eq. (21). The values of the parameters in the potential are shown in Eq. (22), [11]. It is particularly important to notice the relation between λ, σ, and T in Eq. (22). In Eqs. (23) and (24) the two particle Slater sums are expressed in terms of Wiener integrals. The τ-interval has been normalized to (0,1); $r(\tau)$ and S are six-component vectors, one component for each spatial coordinate of each of the particles; $r(\tau)$ is the six-dimensional Wiener path. In the computations relative coordinates are used so only a three dimensional path arises in a two particle computation. It is to be noticed that the path coordinate $r(\tau)$ is multiplied by $\frac{\lambda}{\sqrt{\pi}}$. This factor arises from the normalization of the τ-interval to (0,1). Thus the path has a "range" which is controlled by λ: as $\lambda \to \infty$ (i.e. $T \to \infty$), range $\to 0$; and as $\lambda \to \infty$ (i.e. $T \to 0$), range $\to \infty$. From this one can expect that the statistical error in the Monte Carlo computation will increase as $T \to 0$. The magnitude of the range of the path relative to the magnitude of the range of the interaction is important to keep in mind for a proper appreciation of the computation.

The two particle Slater sum has been calculated at a number of temperatures, [10]. Results at $5^\circ K$ and $30^\circ K$ are shown in Slide 11. The superscript B on W_2 stands for Bose-Einstein statistics. Even at $5^\circ K$ the exchange term is negligible, so actually only the direct term is being seen here. For these results 1000 paths were used and n = 512. The same set of 1000 paths was used for each value of S. The $\mathcal{O}(n^{-1})$ approximation, with broken straight line paths were used. The effect of varying n is shown in Slide 12. A comparison with an independent calculation by Larsen and Kilpatrick at $2^\circ K$ is shown in Slide 13. The second virial coefficient obtained from these computations is shown in Slide 14.

The two particle computations, although interesting, are of questionable practical value since these results can be obtained by other methods, often more efficiently. We have also made three particle computations. (This is mostly the work of Harry F. Jordan for his Ph.D. thesis.) Here this Monte Carlo approach seems to be a powerful and useful tool. The most interesting result that has been obtained here is related to the pair distribution function $n_2(r_1,r_2)$ for He^4. This is expressed as a power series in the density in Eq. (25) of Slide 15. The second term in this expansion, involving W_3, has been computed by these methods. A comparison of our computed $n_2(r_1,r_2)$, based on just the first two terms in the density expansion, with experimental values of this quality [12] is shown in Slide 16. The ratio $\frac{\rho(r)}{\rho_0}$ in the ordinate is equal to $\frac{n_2(r_1,r_2)}{n_2}$. The isolated points are the Monte Carlo results for $10^{\circ}K$ at a density of 0.095 gm/cc; this is a number of density of about 0.22 in units of σ^{-3}. The experimental curve for this density was determined from neutron scattering on liquid Helium at $5.04^{\circ}K$. We have not yet been able to get accurate results at $5^{\circ}K$ because of the large statistical fluctuations. The third virial coefficient, C, has also been computed by Jordan using this Monte Carlo method. Results of this computation and experimental results are shown in Slide 17. The reason for the rather large discrepancy is not known. A conjecture, based on the corresponding phenomenon in classical calculations is that the potential energy function is not sufficiently accurate.

The possibility of making a kind of "superposition approximation" has been explored. Equations for this approximation are displayed in Slide 18. The idea is to replace the Wiener integral of a product of exponentials by a product of Wiener integrals of each exponential. Comparison of the pair distribution function in this approximation with that obtained using a correct evaluation of $W_3(r_1,r_2,r_3)$ is shown in Slide 10. It will be noticed that even at $10^{\circ}K$ this approximation is quite accurate. DeWitt and Fishbane [14] have shown that the error in this approximation is $\mathcal{O}(\lambda^4)$, where λ is the thermal wave length.

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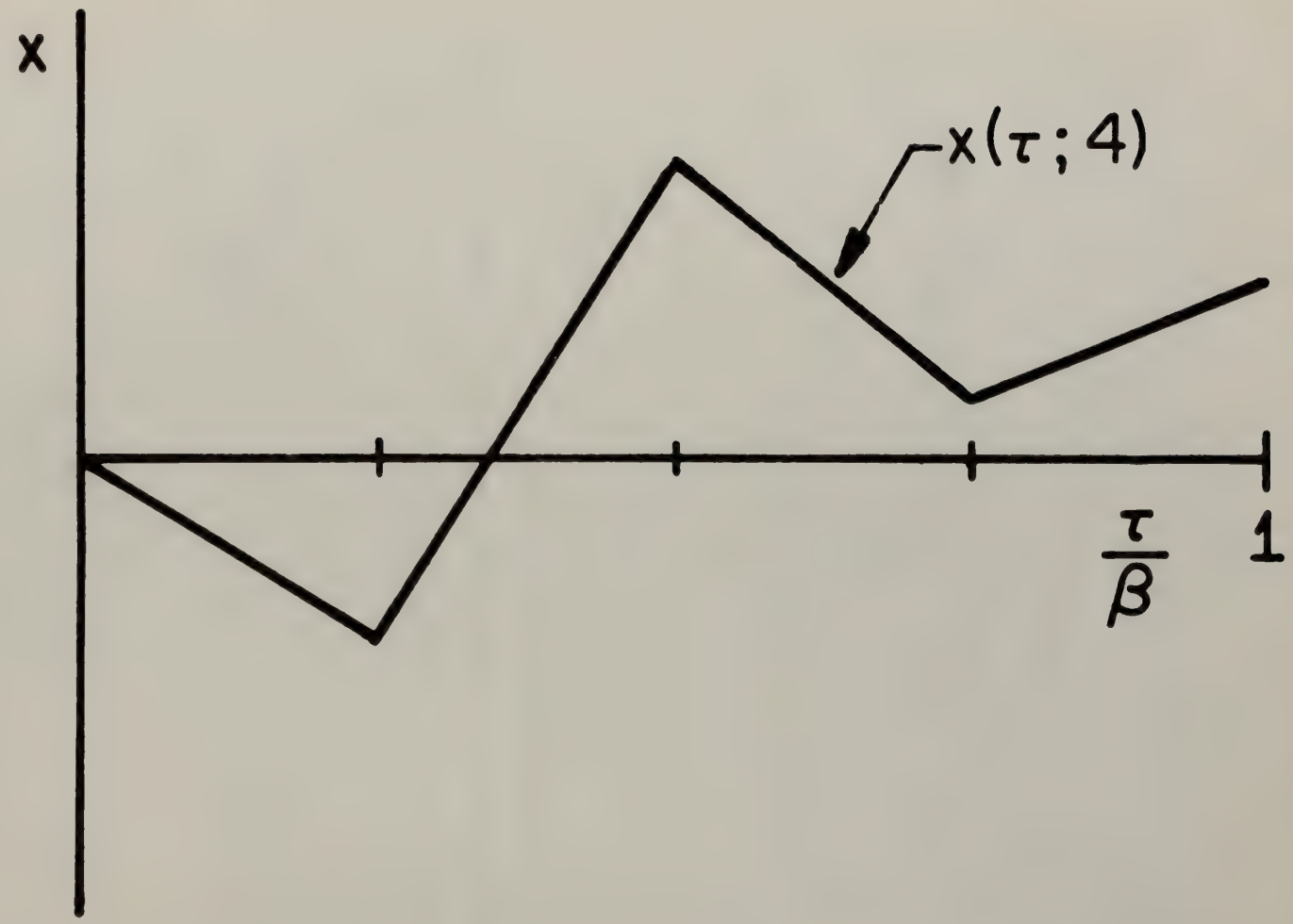


PIECEWISE STRAIGHT PATH WITH n=4

$$E\{F|x(\beta) = X\} = \lim_{n\to\infty} \int_{-\infty}^{+\infty} \cdots \int_{-\infty}^{+\infty} F[x(\tau;n)]\, d\mu_n \quad ; \tag{1}$$

$$d\mu_n = A_n \prod_{i=0}^{n-1} \left[\frac{\exp\left(-\frac{(x_{i+1}-x_i)^2}{2(\tau_{i+1}-\tau_i)} \right)}{\sqrt{2\pi(\tau_{i+1}-\tau_i)}} \right] \prod_{i=1}^{n-1} dx_i \quad ; \tag{2}$$

$$x_i = x(\tau_i;n) \quad , \quad x_0 = 0 \quad , \quad x_n = X \quad ; \tag{3}$$

$$\int_{-\infty}^{+\infty} \cdots \int_{-\infty}^{+\infty} d\mu_n = 1 \quad . \tag{4}$$

Relations for the definition of the conditional Wiener integral $E\{F|x(\beta) = X\}$ of the functional $F[x(\tau)]$.

(5) $$-\frac{1}{2}\frac{d^2\Psi}{dx^2} + V(x)\Psi = E\Psi$$

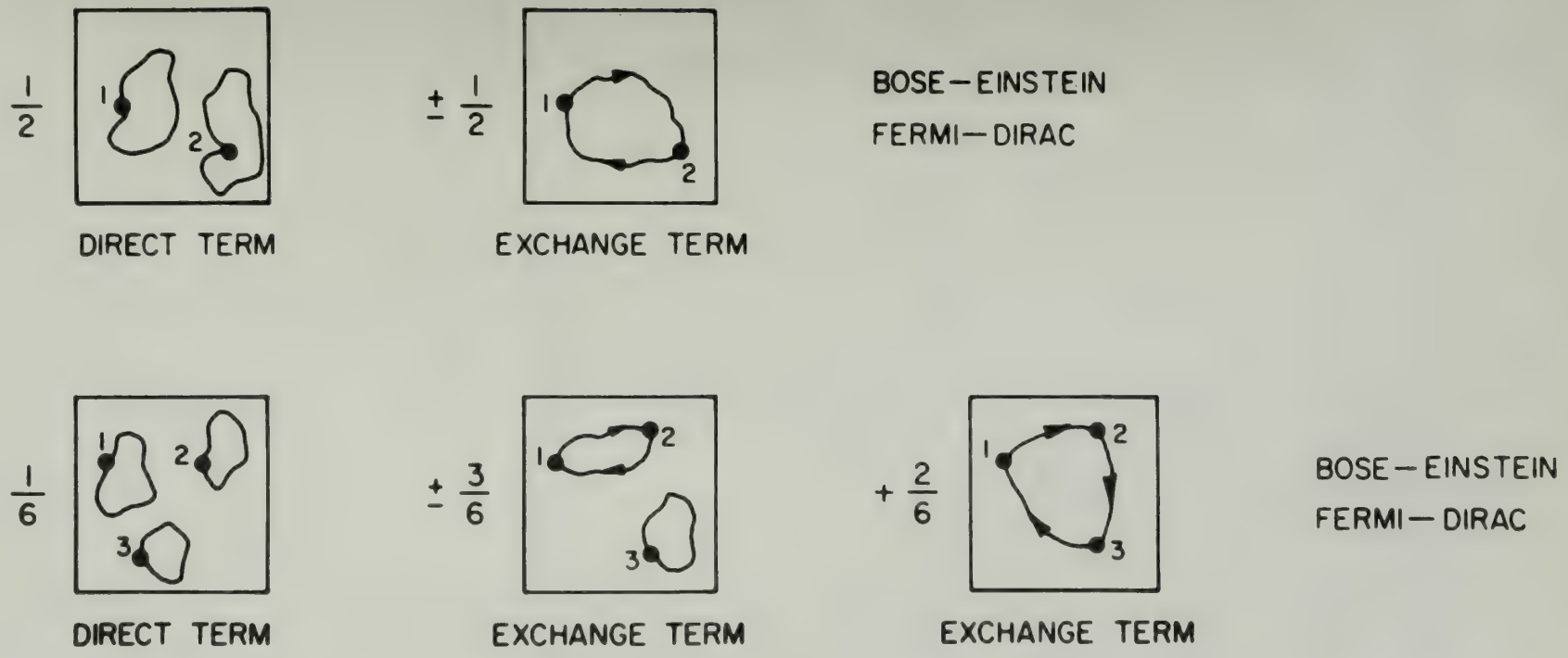
(6) $$(2\pi\beta)^{-1/2}\, e^{-(X'-X)^2/2\beta} \quad E\{F|x(\beta)=X'-X\} = \sum_i \Psi_i^*(X)\,\Psi_i(X')e^{-\beta E_i}$$

(7) $\{\Psi_i\ ,\ E_i\}$ eigenvectors and eigenvalues of (5)

(8) $$F = \exp\left(-\int_0^\beta V(x(\tau) + X)d\tau\right)$$

(9) $$(2\pi\beta)^{-1/2}\int_{-\infty}^{+\infty} E\{F|x(\beta) = 0\}\, dX = \sum_i e^{-\beta E_i}$$

Relations connecting a conditional Wiener integral with the partition function.



DIAGRAMMATIC REPRESENTATION OF WIENER INTEGRALS FOR TWO AND THREE PARTICLE SYSTEMS.

$$E\{F|x(\beta) = 0\} \cong \int_{-\infty}^{+\infty} \cdots \int_{-\infty}^{+\infty} F[x(\tau;n)]\, d\mu_n \tag{10}$$

$$x(\tau;n) = \sqrt{2} \sum_{j=1}^{n-1} \xi_j \frac{\sin j\pi\tau}{j\pi} \tag{11}$$

$$d\mu_n = \prod_{i=1}^{n-1} \frac{e^{-\xi_i^2/2}}{\sqrt{2\pi}}\, d\xi_i \tag{12}$$

The "rectangle" approximation for the conditional Wiener integral. Error is $\mathcal{O}(\frac{1}{n})$.

$\alpha^{1/2}$	$\lvert\rho\rvert < 10^{-2}$	$\lvert\rho\rvert < 10^{-3}$	$\lvert\rho\rvert < 10^{-4}$
0.01	1	1	1
0.04	1	1	1
0.16	1	1	13
0.64	2	21	208
1.00	5	51	$> 500^{a}$
2.56	33	332	$> 500^{b}$

[a] $|\rho| = 1.015 \times 10^{-4}$ when n = 500.

[b] $|\rho| = 6.637 \times 10^{-4}$ when n = 500.

Minimum value of n required in the rectangle approximation to achieve a specified relative error ρ in the partition function for a harmonic oscillator.

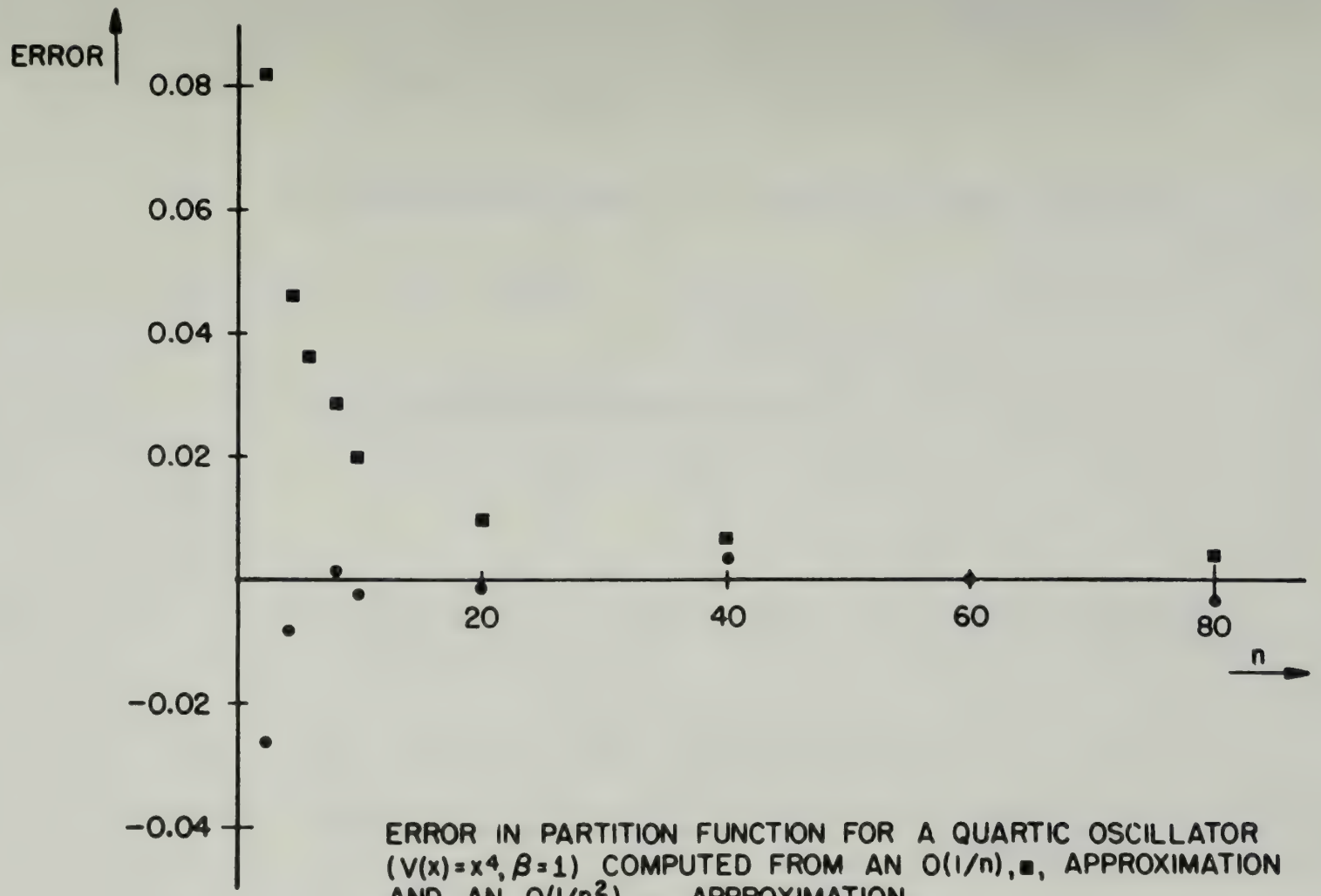
$$\alpha = (\omega\beta)^2 \ , \ V(x) = \frac{\omega^2 x^2}{2} \ , \ \beta = \frac{1}{kT}$$

$$E\{F|x(\beta) = X\} \tilde{=} \int_{-\infty}^{+\infty} \cdots \int_{-\infty}^{+\infty} F[x(\tau;n)]\, g_n\, d\mu_n \tag{13}$$

$$g_n = \prod_{i=1}^{n} \left(1 - \frac{1}{2n^2} \int_0^{\beta} V''(x_{i-1} + (x_i - x_{i-1})\tau)\tau(1-\tau)d\tau \right) \tag{14}$$

$$V'' = \frac{d^2V}{dx^2}, \quad F = \exp\left(- \int_0^{\beta} V(x(\tau))d\tau \right) \tag{15}$$

An approximation formula for the conditional Wiener integral with an error term $\mathcal{O}(n^{-2})$.



ERROR IN PARTITION FUNCTION FOR A QUARTIC OSCILLATOR ($V(x)=x^4, \beta=1$) COMPUTED FROM AN $O(1/n)$, ■, APPROXIMATION AND AN $O(1/n^2)$, •, APPROXIMATION.
10,000 SAMPLE PATHS.

(16) $$p(x_i|x_{i-1},x_{i+1}) = ((2\pi)^2(\tau_i-\tau_{i-1})(\tau_{i+1}-\tau_i))^{-\frac{1}{2}} \exp\left(-\frac{(x_i-x_{i-1})^2}{2(\tau_i-\tau_{i-1})} - \frac{(x_{i+1}-x_i)^2}{2(\tau_{i+1}-\tau_i)}\right)$$

(17) $$x_i = \frac{(\tau_{i+1}-\tau_i)x_{i-1} + (\tau_i-\tau_{i-1})x_{i+1}}{(\tau_{i+1}-\tau_{i-1})} + \xi\left(\frac{(\tau_i-\tau_{i-1})(\tau_{i+1}-\tau_i)}{(\tau_{i+1}-\tau_{i-1})}\right)^{\frac{1}{2}}$$

(18) ξ a Gaussian random variable $\overline{\xi} = 0$, $\overline{\xi^2} = 1$.

The interpolation formula (17) used to generate conditional Wiener paths.

Slater Sum

$$W_N = N!\,\lambda^{3N} \sum_i \Psi_i'(r_1, r_2, \ldots r_N)\, e^{-\beta H_N}\, \Psi_i(r_1, r_2, \ldots, r_N) \tag{19}$$

Thermal Wave Length

$$\lambda = \sqrt{\frac{2\pi\hbar^2\beta}{m}} \qquad \left(\beta = \frac{1}{kT}\right) \tag{20}$$

6-12 potential function

$$V(S) = 4\alpha \left(\left(\frac{\sigma}{S}\right)^{12} - \left(\frac{\sigma}{S}\right)^{6} \right) \quad , \quad S = r_1 - r_2 \tag{21}$$

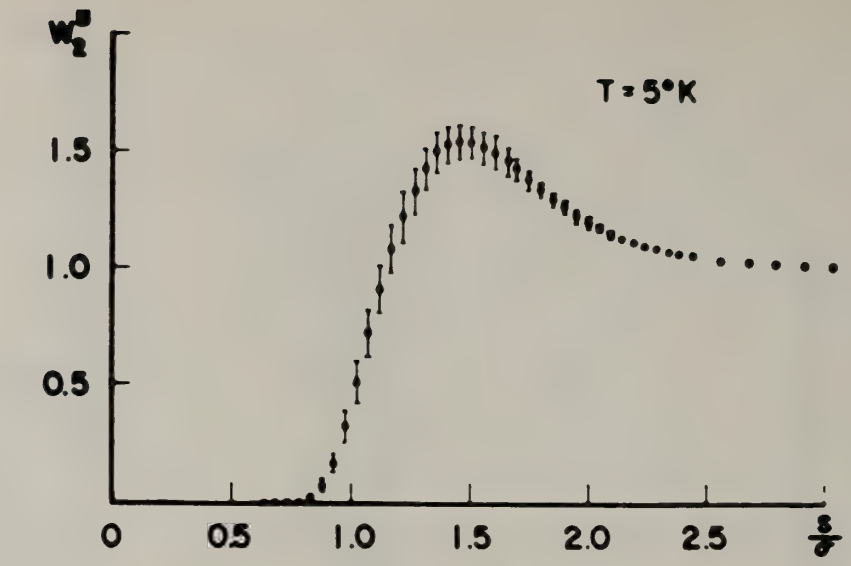
$$\alpha = 10.17\ {}^{\circ}K \quad , \quad \sigma = 2.56 \cdot 10^{-8}\ cm \quad , \quad \lambda = \frac{3.4\sigma}{\sqrt{T}} \quad (He^4) \tag{22}$$

Direct term for 2 particles

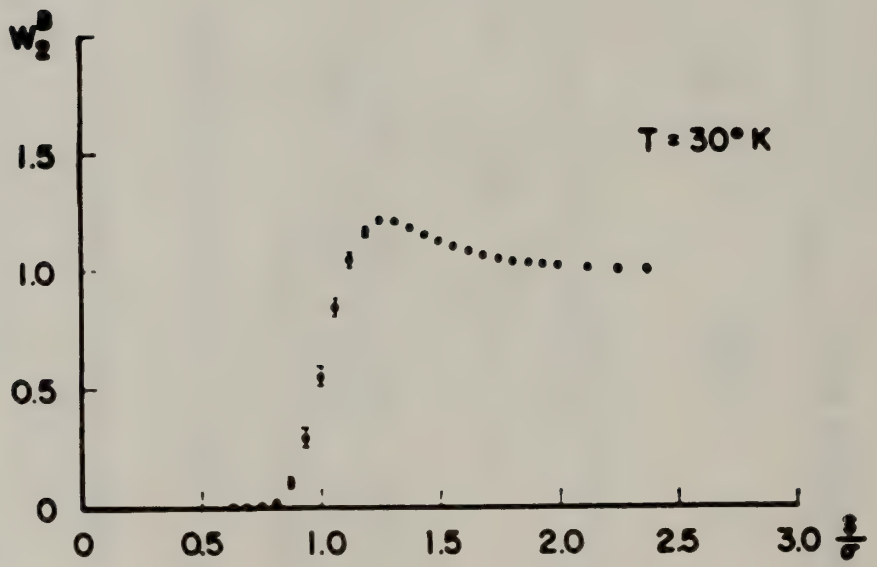
$$W_2^D = E\left\{ \exp\left[-\beta \int_0^1 V\left(\frac{\lambda}{\sqrt{\pi}}\, r(\tau)' + S \right) d\tau \right] \,\middle|\, r(1) = 0 \right\} \tag{23}$$

Exchange term for 2 particles

$$W_2^E = e^{-2\pi S^2/\lambda^2}\, E\left\{ \exp\left[-\beta \int_0^1 V\left(\frac{\lambda}{\sqrt{\pi}}\, r(\tau) + S - 2\tau S \right) d\tau \right] \,\middle|\, r(1) = 0 \right\} \tag{24}$$



(a)



(b)

$W'_2{}^B$ as a function of S/σ for $T = 5°K$ with the Monte Carlo sampling error shown. Total length of the error indicator, represented by the vertical line segment, is twice the standard deviation of the sample mean, represented by the dot. (b). $W'_2{}^B$ as a function of S/σ for $T = 30°K$ with the Monte Carlo sampling error shown. Total length of the error indicator, represented by the vertical line segment, is twice the standard deviation of the sample mean, represented by the dot.

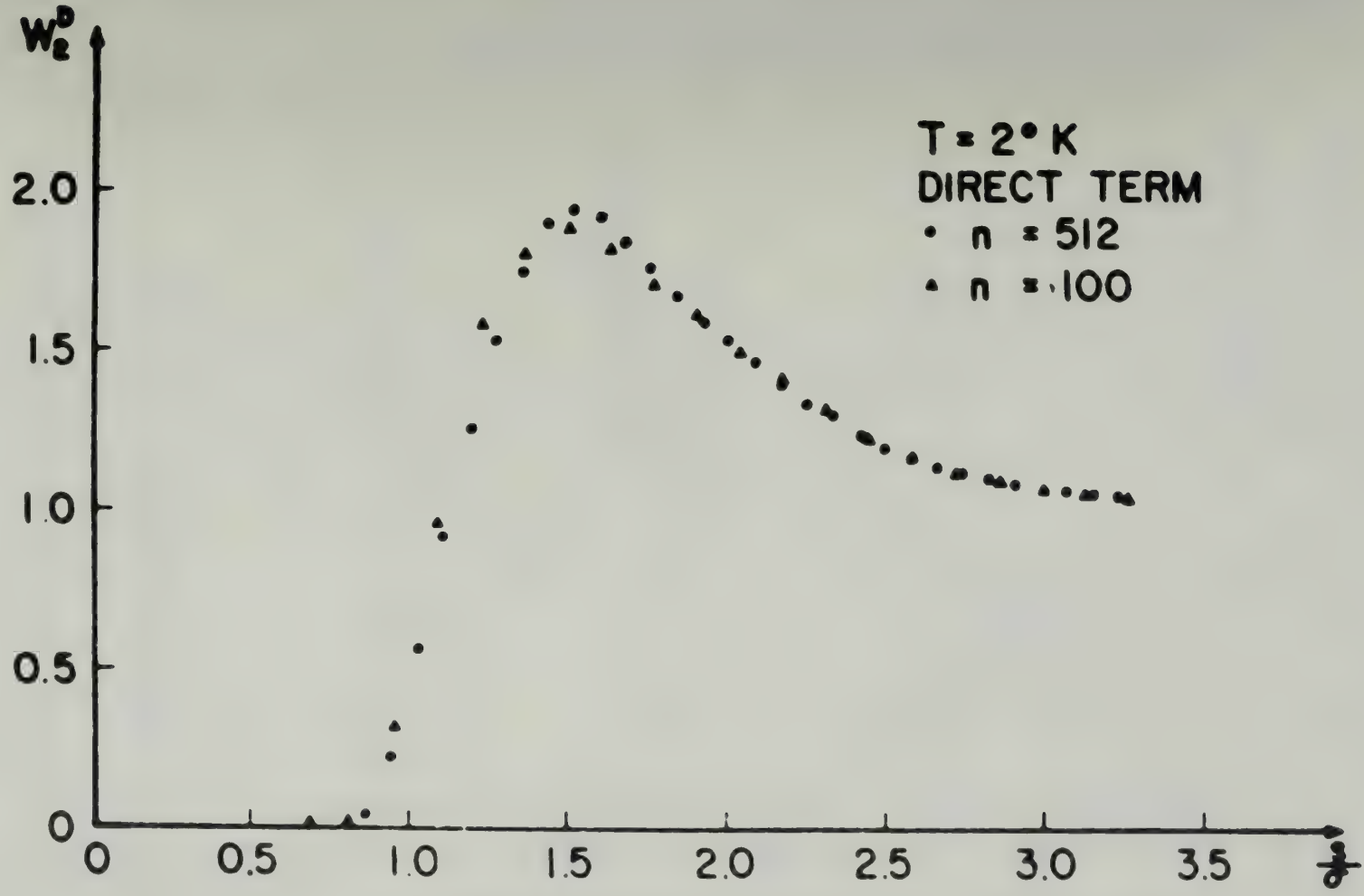
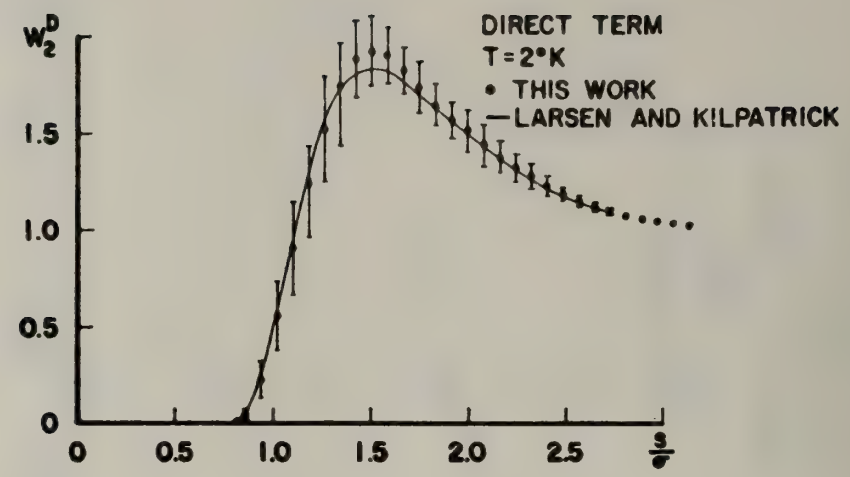
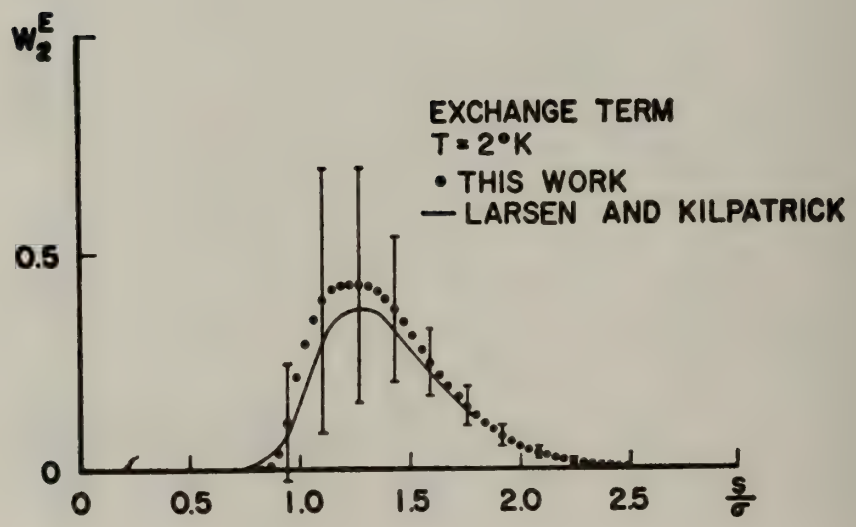


FIG. 6. $W_2{}^D$ (the direct term) at $T = 2°\text{K}$ for $n = 100$ and $n = 512$.



(a)



(b)

Comparison of Monte Carlo results with results of Larsen and Kilpatrick at 2°K. Monte Carlo sampling error is indicated.

The second virial coefficient compared with the computer results of Kilpatrick, Keller, Hammel, and Metropolis and with experiment.

T(°K)	B This work	B Kilpatrick *et al.*	Experiment
2	−182.84	−177.39	−193.3[a]
5	− 59.41	− 59.14	− 62.2[b]
10	− 21.30	− 21.34	− 23.4[b]
20	− 2.49	− 2.53	− 4.04[b]
30	3.68	3.57	2.42[b]
40	6.59	6.49	6.57(40.09°K)[c]
50	8.26	8.16	8.06(50.09°K)[c]
75	10.28	10.14[e]	10.70(75.01°K)[c]
100	11.08	11.02[e]	11.85(100.02°K)[c]
273.18	11.65	11.59[e]	11.77[d]

[a] Obtained by linear extrapolation of the data in W. E. Keller, Phys. Rev. **97**, 1 (1955).
[b] David White, Thor Rubin, Paul Camky, and H. L. Johnson, J. Phys. Chem. **64**, 1607 (1960).
[c] W. H. Keesom, *Helium* (Elsevier, Amsterdam 1942).
[d] W. G. Schneider and J. A. H. Duffie, J. Chem. Phys. **17**, 751 (1949).
[e] Obtained by us from the high-temperature expansion

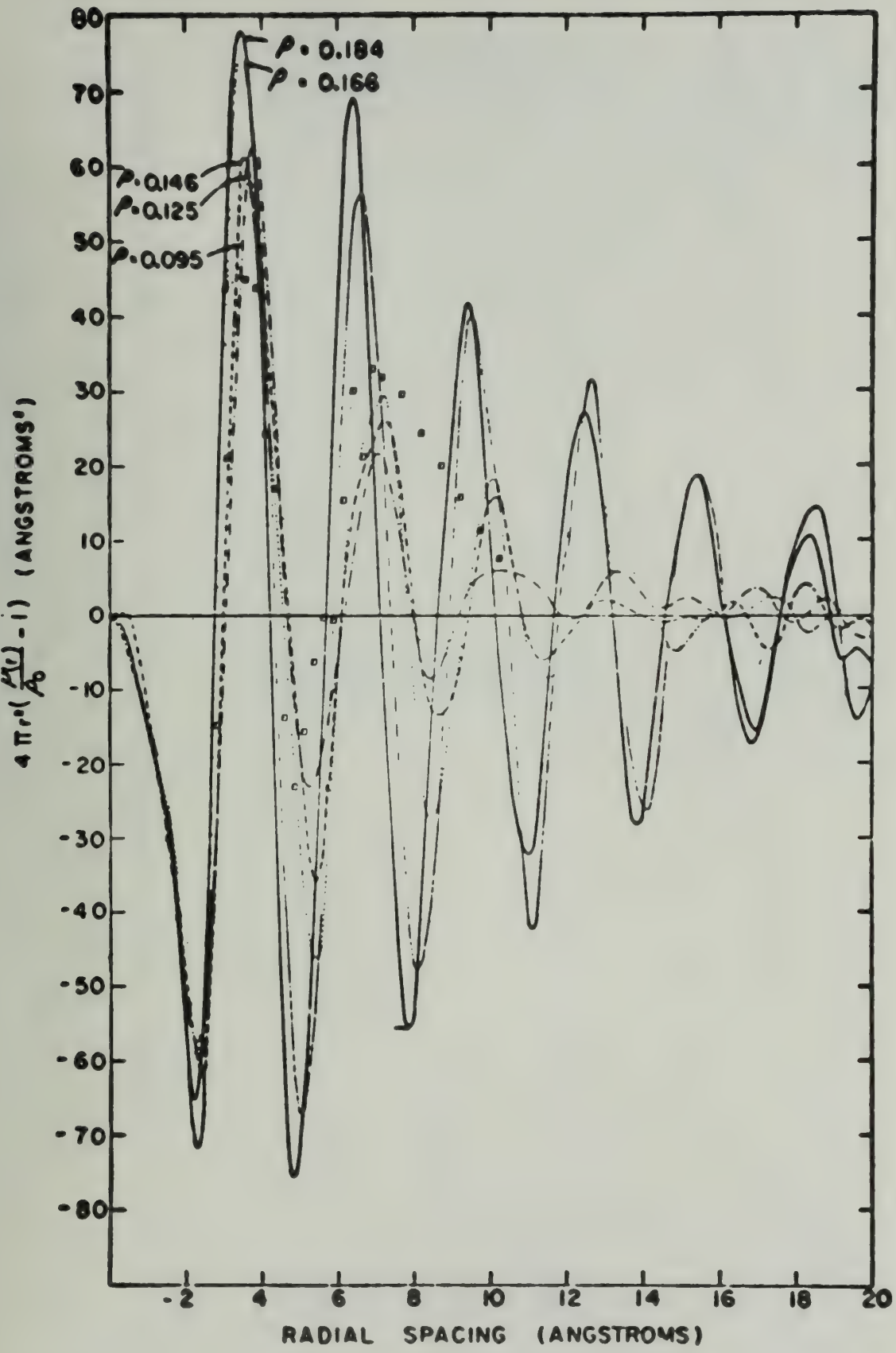
(25) $$n_2(r_1,r_2) = \sum_{k=2}^{\infty} \gamma_k(r_1,r_2)n^k$$

(26) $$n = \text{number density}$$

(27) $$\gamma_2 = W_2(r_1,r_2)$$

(28) $$\gamma_3 = \int \left(W_3(r_1,r_2,r_3) + W_2(r_1,r_2) - 2\, W_2(r_1,r_3)\, W_2(r_1,r_2) \right) dr_3$$

Density expansion for the two particle distribution function.


ρ = 0.184
ρ = 0.168
ρ = 0.146
ρ = 0.125
ρ = 0.095
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-2
4
6
8
10
12
14
16
18
20
RADIAL SPACING (ANGSTROMS)
4πr²(ρ(r)/ρ₀ - 1) (ANGSTROMS⁻¹)

$T(^{o}K)$	$C \frac{cm^6}{mole^2}$ Monte Carlo	$C \frac{cm^6}{mole^2}$ Experimental
10	515	520
20	286	470
30	227	420
40	195	380
50	178	350
75	162	300*
100	150	270*
273	107	150

Third virial coefficient C for He^4 by Monte Carlo and experimental results by Keesom [13].
(*obtained by linear interpolation)

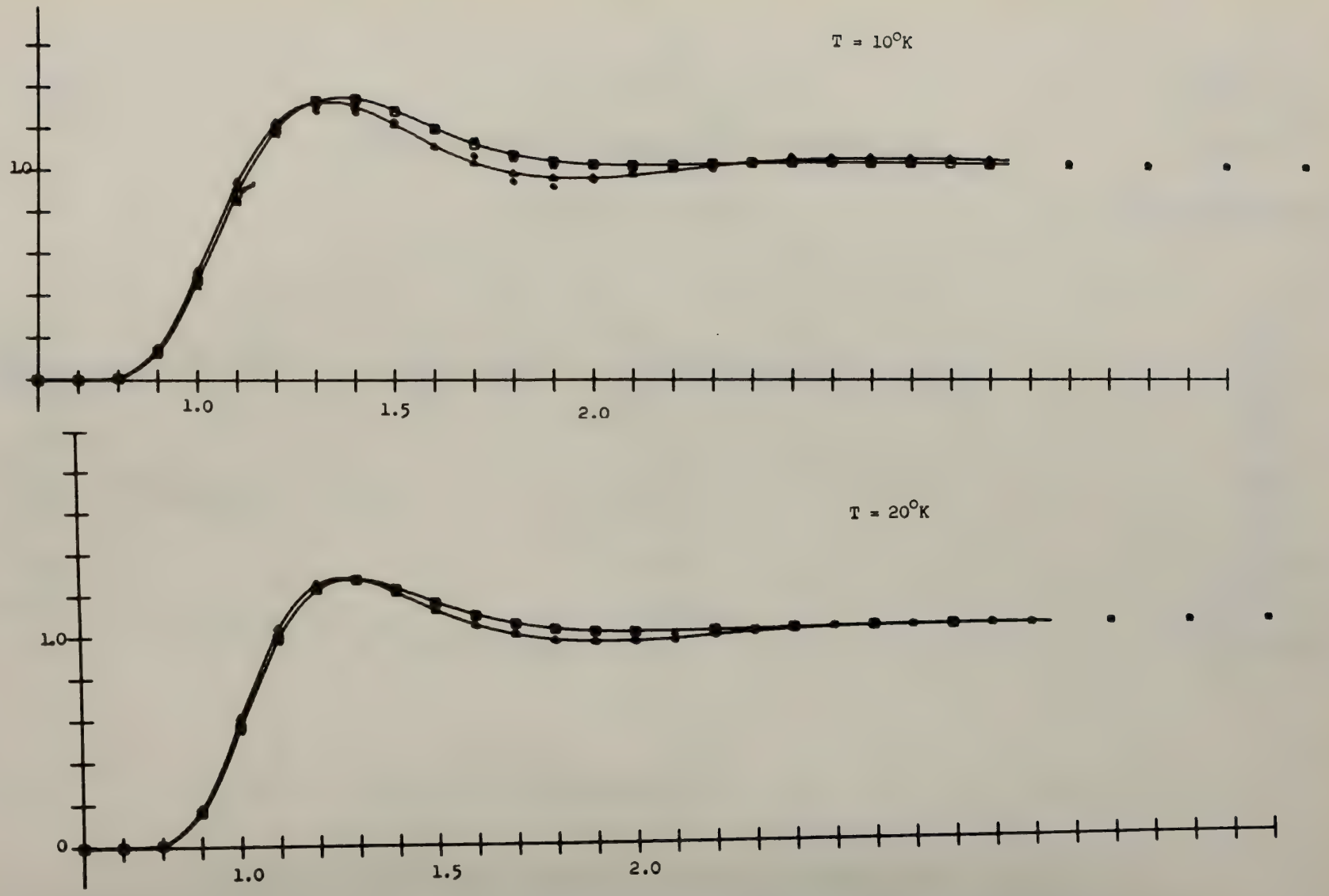
$$W_3(r_1,r_2,r_3) = E\left\{\exp\left(-\beta\int_0^1 (V_{12}+V_{13}+V_{23})d\tau\right) \mid r(1)=0\right\} \cdot$$

$$\tilde{=} E\left\{\exp\left(-\beta\int_0^1 V_{12}d\tau\right) \mid r(1)=0\right\} E\left\{\exp\left(-\beta\int_0^1 V_{13}d\tau\right) \mid r(1)=0\right\} E\left\{\exp\left(-\beta\int_0^1 V_{23}d\tau\right) \mid r(1)=0\right\}$$

In this approximation

$$\frac{n_2}{n^2}(r_1,r_2) = W_2(r_1,r_2)\left\{1 + n\int\left(W_2(r_1,r_3)-1\right)\left(W_2(r_2,r_3)-1\right) dr_3\right\} + \mathcal{O}(n^2)$$

Wiener integral "superposition approximation"



Pair distribution function in the superposition approximation

7. SWITCHING THEORY AND LOGICAL DESIGN

C. R. Baugh, F. Chen and T. Tsuboi continued to program Gomory's algorithms for the design of an optimum network under the direction of Prof. S. Muroga. Baugh's program for a network of three NOR elements based on Gomory's all integer algorithm was completed and tested. Most of the Boolean functions of three variables took about ten seconds. He is planning to expand his program for a network of four or five NOR elements. Tsuboi made a program for a network of threshold elements based on Gomory's mixed integer algorithm but after test runs, we concluded the algorithm's convergence was too slow and decided not to pursue this case. Tsuboi left in February.

T. Ibaraki joined the group in February and started to develop a technique to speed up the convergence of Gomory's all integer algorithm with S. Muroga. The technique was found powerful when we tested it with Baugh's program.

Chen tried to complete a program for a network of threshold elements based on Gomory's all integer algorithm.

T. Slivinski developed an interesting theory for partial threshold functions.

S. Muroga

8. ILLIAC II SERVICE, USE, AND PROGRAM DEVELOPMENT

(This work is supported in part by Contract No. AT(11-1)-1469 of the Atomic Energy Commission and in part by the University of Illinois.)

8.1 ILLIAC II Program Development

8.1.1 System Program Development

The following changes were incorporated into both the Multiplexing Special Register System and the PDP system tapes.

a. Record class 1 (short records) are allowed on the disk file for all users. (This was added primarily for the time sharing system.)

b. The Disk file package in SYSAUX was completely replaced in order to correct a number of problems.

c. New error messages were placed in SYSERR and the monitor trap exits in the system.

d. Corrections in SYSETC, timing and the link to BOOTS were incorporated.

J. Aaron.

8.1.2 Analog I/O

Work was completed on the Analog-Digital Programming System for the ILLIAC II. File 726, describing the Analog-Digital Programming System, was completed. A memorandum was sent to ILLIAC users describing job running via the ILLIAC operators and daily A/D runs were initiated. A new 13 bit analog-to-digital convert was ordered and should be delivered in May.

A. B. Otis, Jr.

8.2 Library Programming

8.2.1 ILLIAC II Library Development

During this period minor changes were made in the following subroutines:

M2-UOI-PRINT-17-NI

IDENTIFICATION--PRINT, READ and PUNCH with input output conversion.

PURPOSE--To provide flexible input and output with the ILLIAC II computer.

F2-UOI-HOUSE-97-FR

IDENTIFICATION--Householder's method for symmetric matrices, a FORTRAN subroutine.

PURPOSE--Reduces a symmetric matrix to tridiagonal form.

F2-UOI-BKTRNS-98-FR

IDENTIFICATION--A FORTRAN subroutine for finding eigenvectors by the method of backtransformation.

PURPOSE--This subroutine is to be used in conjunction with HOUSE (Householder's method for symmetric matrices) and EVINIT (calculation of the eigenvectors of a symmetric tridiagonal matrix by inverse iteration). Given the eigenvectors of the tridiagonal matrix this subroutine will apply to them the appropriate orthogonal transformations used in the Householder reduction to obtain the eigenvectors of the original matrix.

F2-U0I-DECOMP-102-FR

IDENTIFICATION--A FORTRAN subroutine for the Cholesky decomposition of a matrix.

PURPOSE--This subroutine is called by LRCH (a library subroutine for the LR transformation method). It decomposes the matrix $A-\lambda I$ into the product $R^T \cdot R$ where R is an upper triangular matrix.

Also, during this period the following subroutines were added to the library:

S21-U0I-ELLPTC-101-FR

IDENTIFICATION--Evaluation of elliptic integrals and elliptic functions.

PURPOSE--ELLPTC is a collection of FORTRAN subroutines for finding the values of the complete and incomplete elliptic integrals of the first, second and third kinds and the Jacobian elliptic functions sn, cn and dn (for definitions, see METHØD).

F2-U0I-ITRNF1-113-FR

IDENTIFICATION--ITRNF1 is a collection of FORTRAN and NICAP subroutines which finds the solution of a positive definite system of equations by iterative refinement.

PURPOSE--Given a symmetric positive definite nxn matrix A and nr right-hand sides for which Ax=b is to be solved, ITRNF1 calculates a solution using the Cholesky decomposition of A and then successively refines the solution until the maximum correction is less than $2*10^{-11}$ times the maximum x.

F2-U0I-CDET-114-FR

IDENTIFICATION--CDET is a FORTRAN subroutine which performs the Cholesky decomposition of a positive definite matrix.

PURPOSE--CDET is called by ITRNF1 and is designed especially for use with this subroutine. Given the upper triangle of a positive definite symmetric matrix, the Cholesky decomposition $A=LL^T$ is performed and L is stored in the remainder of the A array. The reciprocals of the diagonal elements are stored in a column vector P. The determinant of A is also computed.

F2-U0I-CSOL-115-FR

IDENTIFICATION--CSOL is a FORTRAN subroutine which solves a symmetric positive definite system of equations.

PURPOSE--CSOL is called by ACCSOL and is designed especially for use with the collection of subroutines called by ITRNF1. CSOL must be preceded by CDET which finds L in the Cholesky decomposition of A. Then Ax=b is solved in two steps, Ly=b and $L^Tx=y$, where x is overwritten on y.

F2-U0I-ACCSOL-116-FR

IDENTIFICATION--ACCSOL is a FORTRAN subroutine which successively refines the solution of a positive definite system of equations.

PURPOSE--ACCSOL is called by ITRNF1 and is designed especially for use with this subroutine. Given the lower right triangular matrix L from the Cholesky decomposition of a positive definite symmetric matrix A, ACCSOL finds a solution to Ax=b, and successively refines this solution, using the subroutine CSOL. The iteration may be described as follows:

$x^{(0)} = 0.,\ r^{(s)} = b - AX^{(s)},\ (LL^T)\ d^{(s)} = r^{(s)},\ x^{(s+1)} = x^{(s)} + d^{(s)}$

where $r^{(s)}$ is the residual corresponding to $x^{(s)}$ and $d^{(s)}$ is the correction at this step.

F2-UOI-INPRØD-117-NI

IDENTIFICATION--INPRØD is a NICAP subroutine which computes a double precision sum of products.

PURPOSE--INPRØD is called by CDET, CSØL, ACCSØL, CINV and ACCINV and is designed especially for use with these subroutines. INPRØD will compute, in double precision, the following types of summations:

$$(1)\quad s_o + \sum_{k=0}^{\ell} a(i,k_o^a + k) * x(j,k_o^x + k) = y$$

$$(2)\quad s_o + \sum_{k=0}^{\ell} a(i,k_o^a + k) * x(k_o^x + k,\ j) = y$$

$$(3)\quad s_o + \sum_{k=0}^{\ell} a(k_o^a + k,\ i) * x(k_o^x + k,\ j) = y$$

$$(4)\quad s_o + \sum_{k=0}^{\ell} a(k_o^a + k,\ i) * x(j,k_o^x + k) = y$$

F2-UOI-ITRFN2-118-FR

IDENTIFICATION--ITRFN2 is a collection of FORTRAN and NICAP subroutines which finds the inverse of a positive definite matrix by iterative refinement.

PURPOSE--Given a positive definite symmetric nxn matrix A, ITRFN2 calculates the inverse of A and then successively refines the solution until the maximum correction is less than $2*10^{-11}$ times the maximum x.

F2-UOI-CINV-119-FR

IDENTIFICATION--CINV is a FORTRAN subroutine which finds the inverse of a positive definite matrix.

PURPOSE--CINV is called by ACCINV and is designed especially for use with the collection of subroutines called by ITRFN2. Given a positive definite symmetric n x n matrix A, CINV performs the Cholesky decomposition of A and then uses this to find A^{-1}.

F2-UOI-ACCINV-120-FR

IDENTIFICATION--ACCINV is a FORTRAN subroutine which successively refines the inverse of a positive definite system of equations.

PURPOSE--ACCINV is called by ITRFN2 and is designed especially for use with this subroutine. Given a positive definite symmetric matrix A, ACCINV, using the subroutine CINV, finds the inverse of A using the Cholesky decomposition of A and then refines the inverse as follows: If $X^{(1)}$ is the 1^{st} computed inverse, then $X^{(s+1)} = X^{(s)} + X^{(s)} (I-AX^{(s)})$.

L. D. Fosdick, Project Director
R. Bow
S. Chase
R. Fleck
T. Kuckertz
B. Richardson
N. Smith

8.3 CalComp Digital Incremental Plotter

CCP3NR has been debugged and work is now going on to finish the package of subroutines in FORTRAN for the 360. Work on batch has stopped because it was felt that work on the plotter stuff was more important. A change in CCP1PL is planned so that the picture will go to a scope wired to a pair of special registers for use by K. Walsh.

CCP7RT and CCP8DL of the Plotter package were completed. There are three routines left: CCP4SC, CCP6LN, and CP11EL. Work will begin on CP11EL soon and on the other later.

A FORTRAN version of the plotter package was completed. Modification of subroutine ALL will now be made. Now ALL only reads data cards which have the name of a plotter subroutine on it with the parameters to go with the routine. The modification proposed is when DEFINE is read in, ALL or a similar routine will take the next set of cards, up to END to be a "subroutine" with its own parameters and name, and save it so that if the name is read in again with new parameters, ALL will go through the sequence. This makes it possible to define a figure once and then change it as wished.

R. Lyon

Plotter usage during this quarter has increased to over 300 hours a month. Even though its use by ILLIAC II and other computers has dropped the output from the 7094 has increased considerably. The need for a 3 shift/5 day-week seems to be approaching rapidly. The only thing that presently keeps our service in step with demand is the cooperation of users in the efficient use of the plotting facilities.

With two exceptions the plotter has a remarkable reliability record, about one half hour for each month.

As a thought to the future, a newer and faster plotter is needed with a maintenance of our present plotter for more accurate and reproducable jobs.

C. Carter

8.4 Engineering Test Programming

The following programs were written and/or used in the engineering test programming of ILLIAC II.

1. A test for "access inoperative" was written and used to find a bad ckt. card in the disk channel.
2. A user program was applied for sensitivity test for a bad bit on the drum storage.
3. The engineering test "cavities" tape was formed with disk 1, disk channel, channel 4TTC, channel 5TTC tests.
4. Some channel tests were converted to give output on the teletype.
5. All locked-out portions of the drum were transferred to the disk.
6. Update and correction of drum tests were made.
7. A special flow gating test was written for D.C. marginal purposes.
8. Other channel tests were added to the "cavities" tape.

C. E. Carter

8.5 Engineering Maintenance

Mr. Harold E. Lopeman and Mr. Robert L. Miller attended Digital Equipment Corporation (DEC) school at Maynard, Massachusetts, for the PDP-7/630 during January 2-13, 1967.

The remainder of January was used for updating the interface drawings between the PDP-7 and the 2701 Data Adapter Unit and taking a wiring list from DEC's multiplexer drawings.

Checkout of the interface between the PDP-7 and 2701 logical drawings continued and a complete wiring list was obtained from the drawings during February. Several designs for a transmitter and receiver for the interface were analyzed and checked out. The layouts of the transmitter and receiver cards were then drawn up.

Originally the interface was to be placed in bay 2, below the reader, in the PDP-7. Since it was decided in late January to include DEC's multiplexer in the PDP-7 it seemed more desirable to also place the interface near the multiplexer in bay 3 of the PDP-7. This made it necessary to update both the multiplexer and the interface drawings and wiring lists.

The multiplexer was wired, installed and partially checked out during March. A timing problem was found and has only partially been resolved. Work is continuing towards determining the timing difficulty with the address bits.

H. E. Lopeman
R. L. Miller

8.5.1 ILLIAC II Engineering Log Summary - January, February, March, 1967

Error Analysis - ILLIAC II	January	February	March	Total
Core 0	1	0	0	1
Core 1	1	0	1	2
A.C.	0	1	0	1
Console	0	0	0	0
Disk Channel	3	1	0	4
Drum	4	1	1	6
S.P.U. Channel	2	0	0	2
Tape Channel 4	1	0	0	1
Tape Channel 5	0	0	0	0
D.C.	2	2	1	5
M.A.U.	3	0	1	4
Flow Gating	2	0	1	3
Power Supplies	1	0	2	3
Tape Drives	0	2	2	4
MSRDP	0	1	0	1

8.6 Scheduled Diagnostic Engineering

8.6.1 Maintenance

1. D.C. marginals are done on the C.P.U. each week.
2. The timing tests were used to find a bad zener in A9 step of floating point add.
3. D.C. margin on the drum - 25 showed up a sensitive bit 9.
4. A variation in systems use of magnetic tape was found to be effective in improving the disk dump.
5. The check-out of defective flow gating chassis gives the C.P.U. a complete complement of spares.
6. An intermittant power switch proved to be a problem on the P.D.P. 7

(Major Catastrophe)

The bearings in Drum 1 became defective in the latter part of January. The top and bottom bearing was replaced by a company engineer from Vermont Research Corporation.

C. Carter

8.6.2 Component Failures

Transistors replaced - 23
Zener diodes replaced - 5
Diodes replaced - 1

8.7 Log Summaries

8.7.1 ILLIAC II Use

8.7.1.1 Summary of Use

January, 1967

Scheduled Engineering	58:50
Unscheduled Engineering	23:39
Engineering Development	81:05
Time-Sharing Development and Operation	176:40
Power Off	328:00
Idle	:06
Miscellaneous (operating, tape rewind, tape skipping, tape mounting, rerun of failures, starts of time-sharing)	27:44

Total Use

Training and Education		9:30	
Demonstrations		2:30	
System Update		2:04	
System Development		8:33	
Engineering Maintenance		:25	
Customer Use			
In Systems	24:48		
Short Shots	:06		
Customer Use		24:54	
		Total Use	47:56
		Total Time	744:00

February, 1967

Scheduled Engineering			57:55
Unscheduled Engineering			42:07
Engineering Development			31:51
Time-Sharing Development and Operation			145:10
Power Off			352:00
Miscellaneous (operating, tape rewind, tape skipping, tape mounting, rerun of failures, starts of time-sharing)			14:00
Total Use			
Training and Education		4:10	
System Development		7:53	
Customer Use			
In Systems	16:41		
Short Shots	:13		
Customer Use		16:54	
Total Use			28:57
Total Time			672:00

March, 1967

Scheduled Engineering			65:20
Unscheduled Engineering			27:00
Engineering Development			14:53
Time-Sharing Development and Operation			163:40
Power Off			418:00
Idle			1:10
Miscellaneous (operating, tape rewind, tape skipping, tape mounting, rerun of failures, starts of time-sharing)			17:59
Total Use			
Training and Education		2:57	
System Development		19:37	
Customer Use			
In Systems	13:13		
Short Shots	:11		
Customer Use		13:24	
		Total Use	35:58
		Total Time	744:00

3.7.1.2 Summary of Machine Errors

January, 1967

Main Frame	7
Core	2
Channels	6
Drum	4
Power Supplies	1
Tape Units	1
	21

February, 1967

Main Frame	3
Drum	1
Disk Channel	1
Special Register (MSRDP)	1
Tape Units	2
	8

March, 1967

Main Frame	3
Core	1
Disk Control	1
Drum	1
Tape Drives	2
Power Supplies	2
P.D.P. 7	1
	11

8.7.1.3 Departmental Running Time

January, 1967

	Number of Runs			Number of Specs			Usage in Hours		
Dept.	Tr & Ed	Res	Total	Tr & Ed	Res	Total	Tr & Ed	Res	Total
AAE	132	49	181	5	2	7	5.059	.245	5.304
CE	6	3	9	2	1	3	.072	.560	.632
CHE	57	27	84	3	2	5	.653	.389	1.042
DCS	139	289	428	4	8	12	.489	6.693	7.132
EE	198	82	280	6	5	11	1.445	1.203	2.648
ENGH	51		51	1		1	.436		.436
IE	77		77	1		1	.353		.353
MATH	113		113	1		1	.576		.576
MATRL		82	82		5	5		1.036	1.036
ME	67		67	4		4	.344		.344
PHYCS	2	69	71	1	3	4	.023	2.671	2.694
PHYX		22	22		2	2		.268	.268
SOC		3	3		1	1		.054	.054
TAM	10	50	60	1	5	6	.053	2.176	2.229
XSSS		22	22		1	1		.102	.102
SUB TOTAL	852	698	1550	29	35	64	9.503	15.397	24.900
DCSSYS	0	572	572	0	9	9	0	10.771	10.771
TOTAL	852	1270	2122	29	44	73	9.503	26.168	35.671

T & Ed = Training and Education
Res = Research

February, 1967

Dept.	Number of Runs			Number of Specs			Usage in Hours		
	Tr & Ed	Res	Total	Tr & Ed	Res	Total	Tr & Ed	Res	Total
AAE	119	60	179	8	3	11	2.293	.311	2.604
ADV		23	23		1	1		.255	.255
CE		81	81		2	2		.199	.199
CHE	86	14	100	3	3	6	.680	.277	.957
DCS	158	437	595	6	9	15	.462	9.288	9.750
EE	6	92	98	2	7	9	.072	2.209	2.281
ENGH	2		2	1		1	.003		.003
MATH	56		56	1		1	.123		.123
ME	53		53	6		6	.215		.215
NUCE		15	15		2	2		.077	.077
PHYCS	11	22	33	2	2	4	.094	3.604	3.698
PHYX		29	29		3	3		.397	.397
PSYCH		1	1		1	1		.002	.002
TAM	60	10	70	1	4	5	.224	.068	.292
XSSS		65	65		1	1		.215	.215
SUB TOTAL	551	849	1400	30	38	68	4.166	16.902	21.068
DCSSYS		554	554		9	9		7.649	7.649
TOTAL	551	1403	1954	30	47	77	4.166	24.551	28.717

March, 1967

Department	No. of Runs			No. of Spec.			Time Used		
	Tr & Ed	Res	Total	Tr & Ed	Res	Total	Tr & Ed	Res	Total
AAE	83	26	109	6	2	8	.726	.155	.881
ADV		7	7		1	1		.059	.059
CE	2	86	88	1	3	4	.002	.659	.661
CHE	100	19	119	4	2	6	.692	.214	.906
DCS	76	276	352	3	6	9	.236	3.112	3.348
EE	54	85	139	4	7	11	.205	1.477	1.682
ENGH	9		9	1		1	.077		.077
LIBS		2	2		1	1		.012	.012
MATH	27		27	1		1	.104		.104
MATRL		4	4		2	2		.058	.058
ME	146		146	8		8	.746		.746
MUSIC		7	7		1	1		.290	.290
NUCE	2	48	50	1	2	3	.075	.415	.490
TAM	34	62	96	2	4	6	.083	1.306	1.389
PHYCS	2	54	56	1	1	2	.012	5.458	5.470
PHYX		2	2		1	1		.006	.006
XSSS		38	38		1	1		.177	.177
SUB TOTAL	535	716	1251	32	34	66	2.958	13.398	16.356
DCSSYS		501	501		8	8		11.169	11.169
TOTAL	535	1217	1752	32	42	74	2.958	24.567	27.525

8.7.2 IBM 1401, 1402, 1403 Use

8.7.2.1 Summary of Use

January, 1967

Scheduled Engineering		5:50
Maintenance		2:15
ILLIAC Preparation		150:54
Other (listing, autocoder, reproduce, cobol, operator training, load, SPS, etc.)		28:42
Power Off		328:00
Idle		216:29
Down		11:50
	Total	744:00

February, 1967

Scheduled Engineering		2:30
Unscheduled Engineering		17:20
ILLIAC Preparation		92:44
Other (listing, autocoder, reproduce, cobol, operator training, load, SPS, etc.)		36:50
Power Off		352:00
Idle		170:36
	Total	672:00

March, 1967

Scheduled Engineering		10:55
Unscheduled Engineering		74:15
Maintenance		2:35
ILLIAC Preparation		75:55
Other (listing, autocoder, reproduce, cobol, operator training, load, SPS, etc.)		40:20
Power Off		418:00
Idle		122:00
	Total	744:00

8.7.2.2 Summary of Machine Errors

January, 1967

1401 Main Frame	2
1402 Reader/Punch	1
1403 Printer	1
Total	4

February, 1967

1401 Main Frame	2
1403 Printer	1
Total	3

March, 1967

1401 Main Frame	1
1403 Printer	1
1402 Reader/Punch	1
729 Tape Drive	1
Total	4

9. IBM 7094/1401 SERVICE, USE, AND PROGRAM DEVELOPMENT

(Supported in part by the National Science Foundation under Grant No. NSF-GP-700.)

9.1 New Routines

M2-UØI-BEC1-136-SR BCD to EBCDIC conversion program. This is a complete program which reads in cards punched on an 026 keypunch, and punches out cards in the 029 keypunch code. The input card image is assumed to be in BCD, in the FORTRAN character set (character set H).

Programmed by
H. George Friedman, Jr.
March 28, 1967

Table I - IBM 1401-I

Summary of Use

January, 1967

Scheduled Engineering		5:45
Unscheduled Engineering		7:36
Maintenance		5:30
7094 Preparation		497:06
List/Reproduce		14:34
Code Check		:15
Tape Dump		2:40
Idle		36:48
	Total	570:24

Table II - IBM 1401-I

Summary of Machine Errors

January, 1967

1402 Card Reader Punch		1
	Total	1

Table I - IBM 1401-II

Summary of Use

January, 1967

Scheduled Engineering		6:30
Unscheduled Engineering		22:43
Maintenance		6:36
7094 Preparation		456:23
List/Reproduce		15:01
Code Check		3:37
Tape Dump		2:47
Idle		40:07
	Total	553:44

Table II - IBM 1401-II

Summary of Machine Errors

January, 1967

1402 Card Reader Punch		5
	Total	5

Table I - IBM 1401-IV

Summary of Use

January, 1967

Unscheduled Engineering		2:00
7094 Preparation		9:55
List/Reproduce		10:32
Code Check		4:26
Tape Dump		:25
ILLIAC II Preparation		12:40
Other		:40
	Total	40:38

Table II - IBM 1401-IV

Summary of Machine Errors

January, 1967

1403 Printer		1
	Total	1

Table I - IBM 7094

Summary of Use

January, 1967

Scheduled Engineering			23:34
Unscheduled Engineering			2:23
Maintenance			12:44
Idle			59:15
Miscellaneous (Operator training, tape rewind, system tape mounting, rerun of failing problems, tape skipping, destruction of clock reading)			116:46
TOTAL USE			
Training and Education		80:59	
University Administrative Overhead Use		8:23	
System Modification and Improvement		15:44	
System Updating		2:39	
Customer Use			
In system	276:05		
Relinquish			
AGEC	3:03		
GSBA	:15		
Relinquish Total	3:18		
Special Short Shots	:14		
Customer Use Total		279:37	
Total Use			387:22
Total Time On			602:04

Table II - IBM 7094

Summary of Errors

January, 1967

1116 Printer	1
Total	1

7094 Table III January, 1967

Dept[1]	Number of Runs			Number of Specs			7094 Usage in Hours-Minutes		
	T and E[2]	Res	Total	T and E[2]	Res	Total	T and E[2]	Res	Total
AAE	71	99	170	7	4	11	5 2.7	1 34.4	6 37.2
ACCY	0	25	25	0	3	3	0.0	51.5	51.5
AGE	74	126	200	3	7	10	3 53.1	2 32.7	6 25.9
AGEC	178	193	371	2	13	15	1 15.8	5 53.7	7 9.6
AGRON	193	73	266	1	10	11	1 17.5	39.2	1 56.8
ANS	0	158	158	0	3	3	0.0	1 49.3	1 49.3
ANTH	10	0	10	1	0	1	10.3	0.0	10.3
ASTR	0	133	133	0	7	7	0.0	1 11.8	1 11.8
BECBS	0	218	218	0	5	5	0.0	3 15.1	3 15.1
BINRE	0	7	7	0	1	1	0.0	28.7	28.7
CCDME	6	5	11	1	1	2	41.6	1.3	43.0
CCENE	0	6	6	0	1	1	0.0	40.3	40.3
CCSCS	0	49	49	0	1	1	0.0	27.1	27.1
CE	863	703	1566	9	33	42	8 42.4	18 48.0	27 30.4
CERE	21	0	21	1	0	1	8.6	0.0	8.6
CHE	682	1614	2296	6	47	53	3 13.7	53 12.3	56 26.0
CRC	0	63	63	0	1	1	0.0	1 1.0	1 1.0
CURLA	0	21	21	0	2	2	0.0	18.5	18.5
DCS	545	78	623	5	6	11	8 11.5	3 21.4	11 32.9
DOW	0	13	13	0	1	1	0.0	23.1	23.1
DS	0	73	73	0	4	4	0.0	2 30.1	2 30.1
ECON	0	64	64	0	4	4	0.0	45.4	45.4
ED	0	45	45	0	6	6	0.0	1 7.9	1 7.9
EDADM	0	13	13	0	4	4	0.0	17.1	17.1
EDPSY	47	4	51	1	1	2	1 27.4	2.6	1 30.1
EDTES	0	15	15	0	1	1	0.0	2.9	2.9
EE	279	598	877	10	17	27	1 38.0	13 10.6	14 48.7
ENGH	252	0	252	1	0	1	1 35.4	0.0	1 35.4
ENTOM	0	21	21	0	2	2	0.0	38.8	38.8
FOR	0	11	11	0	1	1	0.0	10.5	10.5
FT	0	26	26	0	1	1	0.0	8.0	8.0
GENE	67	1	68	2	1	3	20.1	0.1	20.3
GEOG	19	3	22	1	2	3	2.9	4.0	7.0
GEOL	0	17	17	0	3	3	0.0	7.1	7.1

Dept[1]	Number of Runs			Number of Specs			7094 Usage in Hours-Minutes		
	T and E[2]	Res	Total	T and E[2]	Res	Total	T and E[2]	Res	Total
GSBA	686	15	701	4	2	6	17 38.8	43.7	18 22.6
HEC	0	16	16	0	2	2	0.0	33.8	33.8
HED	0	1	1	0	1	1	0.0	0.4	0.4
HONOR	0	14	14	0	1	1	0.0	7.7	7.7
HORT	0	86	86	0	4	4	0.0	1 37.8	1 37.8
ICR	0	164	164	0	5	5	0.0	3 11.7	3 11.7
IE	242	30	272	2	1	3	1 4.1	24.6	1 28.8
IED	0	39	39	0	1	1	0.0	41.5	41.5
IGPA	0	9	9	0	1	1	0.0	7.3	7.3
ILR	0	57	57	0	2	2	0.0	23.9	23.9
INADM	0	7	7	0	2	2	0.0	12.1	12.1
IREC	0	20	20	0	2	2	0.0	23.8	23.8
LIBS	0	3	3	0	1	1	0.0	0.6	0.6
LING	0	3	3	0	1	1	0.0	1.1	1.1
MATH	2960	0	2960	3	0	3	16 42.4	0.0	16 42.4
MATRL	0	575	575	0	19	19	0.0	15 31.6	15 31.6
ME	575	253	828	12	15	27	5 16.6	4 44.6	10 01.2
MMPE	0	126	126	0	4	4	0.0	2 33.2	2 33.2
MUSIC	0	14	14	0	1	1	0.0	3.5	3.5
NHS	0	112	112	0	3	3	0.0	2 11.3	2 11.3
NUCE	46	209	255	2	9	11	31.3	2 7.3	2 38.7
OIR	0	54	54	0	1	1	0.0	1 33.7	1 33.7
PEM	0	31	31	0	2	2	0.0	27.8	27.8
PHYB	0	150	150	0	4	4	0.0	1 57.0	1 57.0
PHYCS	4	924	928	2	16	18	0.4	22 30.8	22 31.3
PHYSL	0	60	60	0	3	3	0.0	20.3	20.3
PHYX	0	1650	1650	0	10	10	0.0	76 13.5	76 13.5
POLS	0	41	41	0	3	3	0.0	1 9.1	1 9.1
PSYCH	117	695	812	5	23	28	53.6	11 23.2	12 16.9
REC	0	40	40	0	2	2	0.0	22.4	22.4
SCONS	0	90	90	0	1	1	0.0	1 17.9	1 17.9
SGS	0	55	55	0	1	1	0.0	1 2.3	1 2.3
SOC	28	6	34	1	2	3	12.5	3.8	16.4
SOCW	0	20	20	0	1	1	0.0	59.6	59.6

7094 Table III January, 1967 Continued

Dept[1]	Number of Runs			Number of Specs			7094 Usage in Hours-Minutes		
	T and E[2]	Res	Total	T and E[2]	Res	Total	T and E[2]	Res	Total
SRL	0	24	24	0	1	1	0.0	14.2	14.2
SWS	0	265	265	0	14	14	0.0	4 22.4	4 22.4
TAM	73	211	284	6	15	21	45.7	2 43.6	3 29.3
USGS	0	22	22	0	1	1	0.0	12.5	12.5
VMS	0	7	7	0	1	1	0.0	1.6	1.6
VPP	0	23	23	0	1	1	0.0	7.9	7.9
VTED	0	39	39	0	2	2	0.0	9.8	9.8
WPGU	0	5	5	0	1	1	0.0	6.6	6.6
XSSS	0	76	76	0	1	1	0.0	13.5	13.5
ZOOL	2	106	108	1	3	4	11.1	42.4	53.5
Subtotal	8040	10822	18862	89	379	468	80 59.2	279 36.9	360 36.1
DCSSY[4]	0	653	653	0	19	19	0.0	15 44.2	15 44.2
XDCS[5]	0	35	35	0	1	1	0.0	2 38.6	2 38.6
SSUAD[6]	0	284	284	0	2	2	0.0	8 23.3	8 23.3
Total	8040	11794	19834	89	401	490	80 59.2	306 23.0	387 22.2

1 See list of departmental codes following
2 Training and Education
3 Special Short Shots
4 System Improvement and Modifications
5 System Updating
6 University Administrative Overhead Use

Table I - IBM 1401-I

Summary of Use

February, 1967

Scheduled Engineering		3:30
Unscheduled Engineering		6:40
Maintenance		6:56
7094 Preparation		485:51
List/Reproduce		22:03
Code Check		2:15
Tape Dump		1:38
SMP		3:40
Idle		39:05
	Total	571:38

Table II - IBM 1401-I

Summary of Machine Errors

February, 1967

1401 Main Frame		1
1402 Card Reader Punch		2
1403 Printer		1
	Total	4

Table I - IBM 1401-II

Summary of Use

February, 1967

Scheduled Engineering		4:25
Unscheduled Engineering		8:08
Maintenance		4:56
7094 Preparation		493:51
List/Reproduce		10:04
Code Check		12:00
Tape Dump		3:38
Idle		24:49
	Total	563:51

Table II - IBM 1401-II

Summary of Machine Errors

February, 1967

1402 Card Reader Punch		4
1403 Printer		1
	Total	5

Table I - IBM 1401-IV

Summary of Use

February, 1967

7094 Preparation	37:25
List/Reproduce	21:30
Code Check	12:13
Tape Dump	14:30
ILLIAC II Preparation	3:50
Other	17:10
Total	106:38

Table I - IBM 7094

Summary of Use

February, 1967

Scheduled Engineering				17:17
Unscheduled Engineering				:48
Maintenance				14:24
Idle				37:25
Miscellaneous (Operator training, tape rewind, system tape mounting, rerun of failing problems, tape skipping, destruction of clock reading)				121:29
TOTAL USE				
Training and Education			28:05	
University Administrative Overhead Use			8:08	
System Modification and Improvement			17:56	
System Updating			1:07	
Customer Use				
In system		350:54		
Relinquish				
AGEC	3:18			
CE	:19			
MMPE	:04			
PHYX	:11			
Relinquish total		3:52		
Special Short Shots		:41		
Customer Use Total			355:27	
Total Use				410:43
Total Time On				602:06

Table II - IBM 7094

Summary of Errors

February, 1967

CRT	1
Total	1

Dept[1]	Number of Runs			Number of Specs			7094 Usage in Hours-Minutes		
	T and E[2]	Res	Total	T and E[2]	Res	Total	T and E[2]	Res	Total
AAE	150	133	283	4	4	8	3 41.9	2 00.2	5 42.2
ACCY	0	64	64	0	3	3	0.0	2 2.8	2 2.8
ADV	0	4	4	0	1	1	0.0	2.3	2.3
AGE	103	208	311	4	9	13	41.7	2 38.6	3 20.3
AGEC	0	229	229	0	17	17	0.0	5 45.0	5 45.0
AGRON	23	155	178	2	11	13	20.1	2 22.4	2 42.6
ANS	0	238	238	0	5	5	0.0	1 41.4	1 41.4
ANTH	0	2	2	0	1	1	0.0	7.4	7.4
ARCH	0	11	11	0	1	1	0.0	3.4	3.4
ASTR	0	127	127	0	6	6	0.0	57.3	57.3
BECBS	0	175	175	0	5	5	0.0	2 38.0	2 38.0
BINRE	0	17	17	0	1	1	0.0	22.4	22.4
CCDME	0	1	1	0	1	1	0.0	0.3	0.3
CCSCS	0	57	57	0	1	1	0.0	1 15.0	1 15.0
CE	116	1235	1351	7	38	45	1 19.3	34 45.7	36 5.1
CERE	49	0	49	2	0	2	1 32.4	0.0	1 32.4
CHE	215	1801	2016	7	47	54	1 0.5	54 59.5	56 0.0
CRC	0	71	71	0	1	1	0.0	2 17.0	2 17.0
DCS	916	227	1143	5	8	13	6 41.9	5 13.3	11 55.2
DOW	0	12	12	0	1	1	0.0	17.1	17.1
DS	0	185	185	0	5	5	0.0	6 20.5	6 20.5
ECON	14	122	136	1	5	6	5.5	3 6.5	3 12.1
ED	0	67	67	0	7	7	0.0	1 30.5	1 30.5
EDADM	0	41	41	0	2	2	0.0	43.7	43.7
EDPSY	0	18	18	0	1	1	0.0	30.4	30.4
EE	104	754	858	7	20	27	19.9	13 43.6	14 3.6
ENGH	83	0	83	1	0	1	21.2	0.0	21.2
ENTOM	2	19	21	1	1	2	0.2	10.8	11.0
FOR	0	31	31	0	2	2	0.0	13.1	13.1
FT	0	19	19	0	1	1	0.0	15.5	15.5
GENE	0	13	13	0	1	1	0.0	2.9	2.9
GEOG	0	2	2	0	1	1	0.0	0.7	0.7
GEOL	24	21	45	1	3	4	34.4	1 19.0	1 53.5
GSBA	71	32	103	3	2	5	1 5.1	46.2	1 51.4

Dept[1]	Number of Runs			Number of Specs			7094 Usage in Hours-Minutes		
	T and E[2]	Res	Total	T and E[2]	Res	Total	T and E[2]	Res	Total
HEC	0	11	11	0	2	2	0.0	19.3	19.3
HED	0	38	38	0	1	1	0.0	3 30.2	3 30.2
HORT	0	67	67	0	3	3	0.0	51.8	51.8
ICR	0	263	263	0	4	4	0.0	7 28.0	7 28.0
IE	9	53	62	1	1	2	1.0	52.0	53.0
IED	0	62	62	0	1	1	0.0	1 21.6	1 21.6
IGPA	0	15	15	0	1	1	0.0	8.2	8.2
ILLDM	0	9	9	0	1	1	0.0	22.9	22.9
ILR	0	43	43	0	1	1	0.0	49.3	49.3
INADM	0	2	2	0	1	1	0.0	3.6	3.6
IREC	0	79	79	0	2	2	0.0	2 28.2	2 28.2
LIBS	0	4	4	0	2	2	0.0	5.5	5.5
MATH	1433	4	1437	5	1	6	3 50.9	0.7	3 51.7
MATRL	0	457	457	0	17	17	0.0	9 44.8	9 44.8
ME	937	566	1503	11	21	32	4 49.3	10 25.7	15 15.1
MMPE	0	60	60	0	4	4	0.0	2 36.7	2 36.7
MUSIC	0	42	42	0	1	1	0.0	46.5	46.5
NHS	0	258	258	0	4	4	0.0	8 19.9	8 19.9
NUCE	7	307	314	1	13	14	1.3	3 28.2	3 29.5
OIR	0	89	89	0	1	1	0.0	3 38.5	3 38.5
ORME	0	5	5	0	1	1	0.0	4.6	4.6
PEM	0	55	55	0	5	5	0.0	40.6	40.6
PHYB	0	161	161	0	7	7	0.0	3 10.9	3 10.9
PHYCS	6	1062	1068	2	18	20	0.9	26 23.7	26 24.7
PHYSL	0	39	39	0	2	2	0.0	17.3	17.3
PHYX	0	2155	2155	0	11	11	0.0	76 41.8	76 41.8
POLS	0	37	37	0	3	3	0.0	4 23.3	4 23.3
PSYCH	15	904	919	1	26	27	5.0	16 10.9	16 15.9
REC	0	13	13	0	1	1	0.0	2.6	2.6
SCONS	0	70	70	0	1	1	0.0	48.9	48.9
SGS	0	119	119	0	2	2	0.0	1 46.3	1 46.3
SOC	0	3	3	0	2	2	0.0	5.6	5.6
SOCW	0	4	4	0	1	1	0.0	8.1	8.1
SPCH	0	1	1	0	1	1	0.0	0.4	0.4
SPED	0	20	20	0	1	1	0.0	6.4	6.4

Dept[1]	Number of Runs			Number of Specs			7094 Usage in Hours-Minutes		
	T and E[2]	Res	Total	T and E[2]	Res	Total	T and E[2]	Res	Total
SWS	0	411	411	0	18	18	0.0	6 54.5	6 54.5
TAM	421	511	932	3	13	16	1 31.2	9 19.7	10 51.0
USGS	0	5	5	0	1	1	0.0	1.7	1.7
VPH	0	5	5	0	1	1	0.0	1.5	1.5
VPP	0	34	34	0	1	1	0.0	12.4	12.4
VTED	0	49	49	0	3	3	0.0	13.8	13.8
WPGU	0	5	5	0	1	1	0.0	9.7	9.7
XSSS	0	181	181	0	1	1	0.0	40.9	40.9
ZOOL	0	170	170	0	5	5	0.0	1 23.5	1 23.5
Subtotal	4698	14539	19237	69	420	489	28 4.8	355 28.2	383 33.0
DCSSY[4]	0	699	699	0	17	17	0.0	17 55.7	17 55.7
XDCS[5]	0	41	41	0	1	1	0.0	1 6.7	1 6.7
SSUAD[6]	0	373	373	0	2	2	0.0	8 8.0	8 8.0
Total	4698	15652	20350	69	440	509	28 4.8	382 38.6	410 43.4

1 See list of departmental codes following
2 Training and Education
3 Special Short Shots
4 System Improvement and Modifications
5 System Updating
6 University Administrative Overhead Use

Table I - IBM 1401-I

Summary of Use

March, 1967

Scheduled Engineering	3:10
Unscheduled Engineering	9:09
Maintenance	4:38
7094 Preparation	485:30
List/Reproduce	24:42
Code Check	7:15
Tape Dump	3:13
Idle	7:13
Total	544:50

Table II - IBM 1401-I

Summary of Machine Errors

March, 1967

1402 Card Reader Punch	2
729V Tape Drives	2
Total	4

This table represents usage from March 1 through March 26, 1967. This machine was transferred to the Physics Department on March 27, 1967.

Table I - IBM 1401-II

Summary of Use

March, 1967

Scheduled Engineering	4:30
Unscheduled Engineering	3:40
Maintenance	4:39
7094 Preparation	584:59
List/Reproduce	16:32
Code Check	7:31
Tape Dump	3:38
Idle	18:02
Total	643:31

Table II - IBM 1401-II

Summary of Machine Errors

1401 Main Frame	2
1403 Printer	2
729V Tape Drives	1
Total	5

Table I - IBM 1401-IV

Summary of Use

March, 1967

Scheduled Engineering	5:25
Unscheduled Engineering	:35
Maintenance	1:05
7094 Preparation	160:38
List/Reproduce	24:00
Code Check	13:50
Tape Duplication	1:35
Tape Dump	2:24
ILLIAC II Preparation	22:10
Idle	1:45
Other	8:35
Total	242:02

Table II - IBM 1401-IV

Summary of Machine Errors

March, 1967

1402 Card Reader Punch	1
Total	1

On March 27, 1967, the 1401-IV was moved from DCL to ERL.

Table I - IBM 7094

Summary of Use

March, 1967

Scheduled Engineering				15:39
Unscheduled Engineering				6:08
Maintenance				15:03
Air Conditioning				1:12
Idle				16:45
Miscellaneous (Operator training, tape rewind, system tape mounting, rerun of failing problems, tape skipping, destruction of clock reading)				115:16
TOTAL USE				
Training and Education			71:52	
University Administrative Overhead Use			8:31	
System Modification and Improvement			18:19	
System Updating			1:06	
Customer Use				
In System		407:07		
Relinquish				
AGEC	4:39			
CE	:49			
GSBA	:46			
Relinquish Total		6:14		
Special Short Shots		:47		
Customer Use Total			414:08	
		Total Use		513:56
		Total Time On		683:59

Table II - IBM 7094

Summary of Errors

March, 1967

716 Printer		2
Tape Unit "U"		1
Disk		1
	Total	4

Dept[1]	Number of Runs			Number of Specs			7094 Usage in Hours-Minutes		
	T and E[2]	Res	Total	T and E[2]	Res	Total	T and E[2]	Res	Total
AAE	402	42	444	8	4	12	7 4.0	23.5	7 27.5
ACCY	0	38	38	0	2	2	0.0	1 10.9	1 10.9
ADV	0	30	30	0	1	1	0.0	1 52.2	1 52.2
AGE	359	487	846	3	10	13	4 49.7	6 49.2	11 39.0
AGEC	0	332	332	0	14	14	0.0	11 1.8	11 1.8
AGRON	24	163	187	1	13	14	21.8	2 22.7	2 44.6
ANS	0	172	172	0	5	5	0.0	1 22.0	1 22.0
ANTH	0	8	8	0	2	2	0.0	3.7	3.7
ARCH	0	7	7	0	1	1	0.0	2.1	2.1
ASTR	0	130	130	0	6	6	0.0	1 53.0	1 53.0
BECBS	0	78	78	0	5	5	0.0	1 8.3	1 8.3
BINRE	0	26	26	0	1	1	0.0	9.0	9.0
BIOPH	0	8	8	0	1	1	0.0	0.8	0.8
CCCHE	0	1	1	0	1	1	0.0	1.9	1.9
CCDME	0	13	13	0	1	1	0.0	4.9	4.9
CCSCS	0	6	6	0	1	1	0.0	6.4	6.4
CE	706	1227	1933	9	43	52	3 56.5	35 47.9	39 44.5
CERE	44	0	44	1	0	1	30.0	0.0	30.0
CHE	1111	1903	3014	7	49	56	6 24.8	54 58.4	61 23.3
CRC	0	32	32	0	2	2	0.0	1 23.8	1 23.8
CURLA	0	16	16	0	1	1	0.0	30.3	30.3
DCS	1012	339	1351	5	13	18	5 23.1	6 48.5	12 11.6
DOW	0	7	7	0	1	1	0.0	9.1	9.1
DS	0	158	158	0	4	4	0.0	11 43.7	11 43.7
DUE	0	2	2	0	1	1	0.0	5.8	5.8
ECON	78	156	234	2	7	9	13.4	2 47.2	3 0.7
ED	0	125	125	0	9	9	0.0	1 41.8	1 41.8
EDADM	0	13	13	0	1	1	0.0	27.7	27.7
EDPSY	51	1	52	1	1	2	44.2	0.2	44.4
EDTES	0	24	24	0	1	1	0.0	3 8.7	3 8.7
EE	589	929	1518	8	23	31	2 0.3	13 15.0	15 15.4
ENGH	157	0	157	1	0	1	38.8	0.0	38.8
ENTOM	13	1	14	1	1	2	26.0	5.7	31.8
FOR	0	14	14	0	2	2	0.0	4.7	4.7

Dept[1]	Number of Runs			Number of Specs			7094 Usage in Hours-Minutes		
	T and E[2]	Res	Total	T and E[2]	Res	Total	T and E[2]	Res	Total
FT	0	24	24	0	1	1	0.0	16.2	16.2
GENE	9	8	17	1	1	2	3.0	0.8	3.8
GEOG	3	27	30	1	2	3	11.0	15.1	26.2
GEOL	60	26	86	1	3	4	37.4	7.4	44.8
GSBA	135	61	196	3	2	5	4 59.8	50.5	5 50.4
HEC	0	8	8	0	2	2	0.0	33.4	33.4
HED	0	92	92	0	1	1	0.0	2 42.5	2 42.5
HLTHS	0	7	7	0	1	1	0.0	1 2.0	1 2.0
HORT	0	30	30	0	3	3	0.0	32.6	32.6
ICR	0	183	183	0	3	3	0.0	6 55.9	6 55.9
IE	126	18	144	1	1	2	26.5	3.3	29.9
IED	0	8	8	0	1	1	0.0	12.4	12.4
ICPA	0	27	27	0	1	1	0.0	19.7	19.7
ILLDM	0	5	5	0	1	1	0.0	39.5	39.5
ILR	0	37	37	0	1	1	0.0	46.4	46.4
INADM	0	4	4	0	1	1	0.0	7.4	7.4
IREC	0	59	59	0	2	2	0.0	54.2	54.2
ISDA	0	5	5	0	1	1	0.0	10.3	10.3
LIBS	0	16	16	0	2	2	0.0	12.6	12.6
MATH	6867	10	6877	4	1	5	19 50.9	27.7	20 18.7
MATRL	0	546	546	0	22	22	0.0	8 56.6	8 56.6
ME	1710	359	2069	15	17	32	7 40.3	5 55.1	13 35.5
MMPE	0	82	82	0	3	3	0.0	2 37.6	2 37.6
MUSIC	0	64	64	0	1	1	0.0	43.3	43.3
NHS	0	406	406	0	4	4	0.0	5 37.6	5 37.6
NUCE	35	596	631	3	14	17	11.6	6 52.0	7 3.7
OIR	0	227	227	0	2	2	0.0	6 25.2	6 25.2
ORME	0	22	22	0	1	1	0.0	1 5.3	1 5.3
PEM	0	20	20	0	3	3	0.0	20.9	20.9
PHYB	0	166	166	0	7	7	0.0	2 21.5	2 21.5
PHYCS	46	1025	1071	4	20	24	7.0	24 9.5	24 16.6
PHYSL	0	54	54	0	2	2	0.0	18.4	18.4
PHYX	0	2369	2369	0	11	11	0.0	133 31.6	133 31.6
POLS	0	19	19	0	4	4	0.0	1 4.9	1 4.9
PSYCH	120	693	813	2	25	27	1 25.6	15 10.0	16 35.6
REC	23	10	33	1	2	3	12.4	5.0	17.5

Dept[1]	Number of Runs			Number of Specs			7094 Usage in Hours-Minutes		
	T and E[2]	Res	Total	T and E[2]	Res	Total	T and E[2]	Res	Total
SCONS	0	96	96	0	1	1	0.0	1 13.9	1 13.9
SGS	0	85	85	0	2	2	0.0	1 6.0	1 6.0
SOC	53	36	89	1	3	4	35.6	28.1	1 3.8
SOCW	0	43	43	0	1	1	0.0	1 30.4	1 30.4
SPCH	0	3	3	0	2	2	0.0	24.2	24.2
SPED	0	65	65	0	1	1	0.0	53.6	53.6
SWS	0	287	287	0	12	12	0.0	3 56.1	3 56.1
TAM	500	448	948	7	14	21	2 57.2	8 4.3	11 1.5
VMS	0	1	1	0	1	1	0.0	0.2	0.2
VPH	0	5	5	0	1	1	0.0	3.1	3.1
VPP	0	16	16	0	1	1	0.0	2.9	2.9
VTED	0	39	39	0	2	2	0.0	11.2	11.2
WPGU	0	6	6	0	1	1	0.0	9.1	9.1
XSSS	0	188	188	0	1	1	0.0	47.2	47.2
ZOOL	0	246	246	0	4	4	0.0	1 16.7	1 16.7
Subtotal	14233	15365	29598	91	443	534	71 52.4	414 7.6	486 0.0
DCSSY[4]	0	780	780	0	19	19	0.0	18 18.9	18 18.9
XDCS[5]	0	35	35	0	1	1	0.0	1 6.4	1 6.4
SSUAD[6]	0	270	270	0	2	2	0.0	8 30.6	8 30.6
Total	14233	16450	30683	91	465	556	71 52.4	442 3.5	513 55.9

1 See list of departmental codes following
2 Training and Education
3 Special Short Shots
4 System Improvement and Modifications
5 System Updating
6 University Administrative Overhead Use

Quarterly Summary of Departmental Running Time

January, February, March 1967

Dept[1]	Number of Runs			Number of Specs			7094 Usage in Hours-Minutes		
	T and E[2]	Res	Total	T and E[2]	Res	Total	T and E[2]	Res	Total
AAE	623	274	897	19	12	21	15 48.7	3 58.3	19 47.0
ACCY	0	127	127	0	8	8	0.0	4 5.3	4 5.3
ADV	0	34	34	0	2	2	0.0	1 54.5	1 54.5
AGE	536	821	1357	10	26	36	9 24.7	12 0.6	21 25.3
AGEC	178	754	932	2	44	46	1 15.8	22 40.6	23 56.5
AGRON	240	391	631	4	34	38	1 59.5	5 24.5	7 24.1
ANS	0	568	568	0	13	13	0.0	4 52.9	4 52.9
ANTH	10	10	20	1	3	4	10.3	11.2	21.6
ARCH	0	18	18	0	2	2	0.0	5.6	5.6
ASTR	0	390	390	0	19	19	0.0	4 2.3	4 2.3
BECBS	0	471	471	0	15	15	0.0	7 1.6	7 1.6
BINRE	0	50	50	0	3	3	0.0	1 0.3	1 0.3
BIOPH	0	8	8	0	1	1	0.0	0.8	0.8
CCCHE	0	1	1	0	1	1	0.0	1.9	1.9
CCDME	6	19	25	1	3	4	41.6	6.6	48.2
CCENE	0	6	6	0	1	1	0.0	40.3	40.3
CCSCS	0	112	112	0	3	3	0.0	1 48.7	1 48.7
CE	1685	3165	4850	25	114	139	13 58.3	89 21.7	103 20.1
CERE	114	0	114	4	0	4	2 11.2	0.0	2 11.2
CHE	2008	5318	7326	20	143	163	10 39.1	163 10.3	173 49.4
CRC	0	166	166	0	4	4	0.0	4 41.9	4 41.9
CURLA	0	37	37	0	3	3	0.0	48.8	48.8
DCS	2473	644	3117	15	27	42	20 16.6	15 23.2	35 39.9
DOW	0	32	32	0	3	3	0.0	49.4	49.4
DS	0	416	416	0	13	13	0.0	20 34.4	20 34.4
DUE	0	2	2	0	1	1	0.0	5.8	5.8
ECON	92	342	434	3	16	19	19.0	6 39.2	6 58.3
EE	972	2281	3253	25	60	85	3 58.4	40 9.3	44 7.7
ED	0	237	237	0	22	22	0.0	4 20.3	4 20.3
EDADM	0	67	67	0	7	7	0.0	1 28.7	1 28.7
EDPSY	98	23	121	2	3	5	2 11.6	33.4	2 45.1
EDTES	0	39	39	0	2	2	0.0	3 11.7	3 11.7
ENGH	492	0	492	3	0	3	2 35.5	0.0	2 35.5
ENTOM	15	41	56	2	4	6	26.3	55.4	1 21.8

Quarterly Summary of Departmental Running Time

January, February, March 1967 Continued

Dept[1]	Number of Runs			Number of Specs			7094 Usage in Hours-Minutes		
	T and E[2]	Res	Total	T and E[2]	Res	Total	T and E[2]	Res	Total
FOR	0	56	56	0	5	5	0.0	28.4	28.4
FT	0	69	69	0	3	3	0.0	39.8	39.8
GENE	76	22	98	3	3	6	23.2	3.9	27.1
GEOG	22	32	54	2	5	7	14.0	19.9	34.0
GEOL	84	64	148	2	9	11	1 11.9	1 33.7	2 45.6
GSBA	892	108	1000	10	6	16	23 43.8	2 20.6	26 4.4
HEC	0	35	35	0	6	6	0.0	1 26.6	1 26.6
HED	0	131	131	0	3	3	0.0	6 13.2	6 13.2
HLTHS	0	7	7	0	1	1	0.0	1 2.0	1 2.0
HONOR	0	14	14	0	1	1	0.0	7.7	7.7
HORT	0	183	183	0	10	10	0.0	3 2.3	3 2.3
ICR	0	610	610	0	12	12	0.0	17 35.7	17 35.7
IE	377	101	478	4	3	7	1 31.7	1 20.0	2 51.8
IED	0	109	109	0	3	3	0.0	2 15.5	2 15.5
IGPA	0	51	51	0	3	3	0.0	35.3	35.3
ILLDM	0	14	14	0	2	2	0.0	1 2.5	1 2.5
ILR	0	137	137	0	4	4	0.0	1 59.6	1 59.6
INADM	0	13	13	0	4	4	0.0	23.2	23.2
IREC	0	158	158	0	6	6	0.0	3 46.4	3 46.4
ISEDA	0	5	5	0	1	1	0.0	10.3	10.3
LIBS	0	23	23	0	5	5	0.0	18.8	18.8
LING	0	3	3	0	1	1	0.0	1.1	1.1
MATH	11260	14	11274	12	2	14	40 24.4	28.4	40 52.9
MATRL	0	1578	1578	0	58	58	0.0	34 13.2	34 13.2
ME	3222	1178	4400	38	53	91	17 46.2	21 5.6	38 51.9
MMPE	0	268	268	0	11	11	0.0	7 47.6	7 47.6
MUSIC	0	120	120	0	3	3	0.0	1 33.4	1 33.4
NHS	0	776	776	0	11	11	0.0	16 8.9	16 8.9
NUCE	88	1112	1200	6	36	42	44.3	12 27.6	13 12.0
OIR	0	370	370	0	4	4	0.0	11 37.6	11 37.6
ORME	0	27	27	0	2	2	0.0	1 10.0	1 10.0
PEM	0	106	106	0	10	10	0.0	1 29.5	1 29.5
PHYB	0	477	477	0	18	18	0.0	7 29.6	7 29.6
PHYCS	56	3011	3067	8	54	62	8.4	73 4.2	73 12.7
PHYSL	0	153	153	0	7	7	0.0	56.2	56.2
PHYX	0	6174	6174	0	32	32	0.0	286 27.1	286 27.1

Quarterly Summary of Departmental Running Time

January, February, March 1967 Continued

Dept[1]	Number of Runs			Number of Specs			7094 Usage in Hours-Minutes		
	T and E[2]	Res	Total	T and E[2]	Res	Total	T and E[2]	Res	Total
POLS	0	97	97	0	10	10	0.0	6 37.4	6 37.4
PSYCH	252	2292	2544	8	74	82	2 24.3	42 44.2	45 8.5
REC	23	63	86	1	5	6	12.4	30.1	42.5
SCONS	0	256	256	0	3	3	0.0	3 20.8	3 20.8
SGS	0	259	259	0	5	5	0.0	3 54.8	3 54.8
SOC	81	45	126	2	7	9	48.2	37.7	1 25.9
SOCW	0	67	67	0	3	3	0.0	2 38.2	2 38.2
SPCH	0	4	4	0	3	3	0.0	24.7	24.7
SPED	0	85	85	0	2	2	0.0	1 0.1	1 0.1
SRL	0	24	24	0	1	1	0.0	14.2	14.2
SWS	0	963	963	0	44	44	0.0	15 13.2	15 13.2
TAM	994	1170	2164	16	42	58	5 14.2	20 7.7	25 22.0
USGS	0	27	27	0	2	2	0.0	14.2	14.2
VMS	0	8	8	0	2	2	0.0	1.8	1.8
VPH	0	10	10	0	2	2	0.0	4.6	4.6
VPP	0	73	73	0	3	3	0.0	23.3	23.3
VTED	0	127	127	0	7	7	0.0	35.0	35.0
WPGU	0	16	16	0	3	3	0.0	25.4	25.4
XSSS	0	445	445	0	3	3	0.0	1 41.7	1 41.7
ZOOL	2	522	524	1	12	13	11.1	3 22.6	3 33.8
Subtotal	26971	40726	67697	249	1242	1491	180 56.5	1049 12.4	1230 8.9
DCSSY[4]	0	2132	2132	0	55	55	0.0	51 58.9	51 58.9
XDCS[5]	0	111	111	0	3	3	0.0	4 51.8	4 51.8
SSUAD[6]	0	927	927	0	6	6	0.0	25 2.1	25 2.1
Total	26971	43896	70867	249	1306	1551	180 56.5	1131 5.2	1312 1.7

1 See list of departmental codes following
2 Training and Education
3 Special Short Shots
4 System Improvement and Modifications
5 System Updating
6 University Administrative Overhead Use

LIST OF DEPARTMENT CODES

IF YOUR DEPARTMENT OR OFFICE DOES NOT APPEAR ON THIS LIST, PLEASE WRITE ITS FULL NAME IN THE DEPARTMENT FIELD (B) ON THE PROBLE SPECIFICATION FORM EVEN THOUGH IT WILL REQUIRE MORE THAN 6 CHARACTERS.

ACCY	ACCOUNTANCY
ADMREC	ADMISSIONS AND RECORDS
ADV	ADVERTISING
AAE	AERONAUTICAL AND ASTRONAUTICAL ENGINEERING
AGEC	AGRICULTURAL ECONOMICS
AGED	AGRICULTURAL EDUCATION
AGE	AGRICULTURAL ENGINEERING
AGREXT	AGRICULTURAL EXTENSION
AGR	AGRICULTURE
AGRON	AGRONOMY
ANS	ANIMAL SCIENCE
ANTH	ANTHROPOLOGY
ARCH	ARCHITECTURE
ART	ART
ASTR	ASTRONOMY
BIOPH	BIOPHYSICS
BOT	BOTANY
BCMPL	BUREAU OF COMMUNITY PLANNING
BECBSR	BUREAU OF ECONOMIC AND BUSINESS RESEARCH
BEDRES	BUREAU OF EDUCATIONAL RESEARCH
GSBA	BUSINESS ADMINISTRATION, GRADUATE SCHOOL
CZR	CENTER FOR ZOONOSES RESEARCH
CERE	CERAMIC ENGINEERING
CHE	CHEMISTRY AND CHEMICAL ENGINEERING
CRC	CHILDREN'S RESEARCH CENTER
CP	CITY PLANNING
CE	CIVIL ENGINEERING
CCARCH	ARCHITECTURE (CHICAGO CIRCLE)
COMM	COMMUNICATIONS
CSL	COORDINATED SCIENCE LABORATORY
DS	DAIRY SCIENCE
DT	DAIRY TECHNOLOGY
DNSTUD	DEAN OF STUDENTS
DCS	DEPARTMENT OF COMPUTER SCIENCE
DGS	DIVISION OF GENERAL STUDIES L A S
DUE	DIVISION OF UNIVERSITY EXTENSION
ECON	ECONOMICS
ED	EDUCATION
EDPSY	EDUCATION PSYCHOLOGY
EDADM	EDUCATIONAL ADMINISTRATION AND SUPERVISION
EDTEST	EDUCATIONAL TESTING
EE	ELECTRICAL ENGINEERING

ENGLSH	ENGLISH
EDC	EXTENSION DIVISION, COUNSELING
FIN	FINANCE
FT	FOOD SCIENCE
FOR	FORESTRY
GENE	GENERAL ENGINEERING
GEOG	GEOGRAPHY
GEOL	GEOLOGY
GRDCOL	GRADUATE COLLEGE
GSBA	GRADUATE SCHOOL OF BUSINESS ADMINISTRATION
HED	HEALTH EDUCATION
HLTHSV	HEALTH SERVICE
HEC	HOME ECONOMICS
HORT	HORTICULTURE
ILLDMH	ILLINOIS DEPARTMENT OF MENTAL HEALTH
INADM	INDUSTRIAL ADMINISTRATION
IED	INDUSTRIAL EDUCATION
IE	INDUSTRIAL ENGINEERING
IREC	INSTITUTE FOR RESEARCH ON EXCEPTIONAL CHILDREN
ICR	INSTITUTE OF COMMUNICATIONS RESEARCH
IGPA	INSTITUTE OF GOVERNMENT AND PUBLIC AFFAIRS
ILR	INSTITUTE OF LABOR AND INDUSTRIAL RELATIONS
LIR	LABOR AND INDUSTRIAL RELATIONS
LAW	LAW
LIBS	LIBRARY SCIENCE
MKTG	MARKETING
MATRL	MATERIALS RESEARCH LABORATORY
MATH	MATHEMATICS
ME	MECHANICAL ENGINEERING
MRL	MEDICAL RESEARCH LAB
MEDIC	MEDICINE
MRHA	MEN'S RESIDENCE HALL ASSOCIATION
MRHARC	MEN'S RESIDENCE HALL ASSOCIATION ROCKET CLUB
MMPE	MINING, METALLURGY AND PETROLEUM ENGINEERING
MUSIC	MUSIC
NHS	NATURAL HISTORY SURVEY
NUCE	NUCLEAR ENGINEERING
OIR	OFFICE OF INSTRUCTIONAL RESOURCES
PHIL	PHILOSOPHY
PEM	PHYSICAL EDUCATION FOR MEN AND GRADUATE PE
PEW	PHYSICAL EDUCATION FOR WOMEN
PHYX	PHYSICS
PHYSL	PHYSIOLOGY
PLPA	PLANT PATHOLOGY
POLS	POLITICAL SCIENCE
PSYTRY	PSYCHIATRY
PSYCH	PSYCHOLOGY
REC	RECREATION
SHCBRC	SMALL HOMES COUNCIL, BUREAU OF RESIDENTIAL CONSTRUCTION
SOCW	SOCIAL WORK
SOC	SOCIOLOGY

SCONS	SOIL CONSERVATION SERVICE
SPCH	SPEECH AND THEATRE
SGS	STATE GEOLOGICAL SURVEY
SWS	STATE WATER SURVEY
SSU	STATISTICAL SERVICES UNIT
SCS	STUDENT COUNSELING SERVICE
SRL	SURVEY RESEARCH LABORATORY
TAM	THEORETICAL AND APPLIED MECHANICS
USGS	U.S. GEOLOGICAL SERVICE
UNIHI	UNIVERSITY HIGH SCHOOL
VAH	VETERINARY ANATOMY AND HISTOLOGY
VCM	VETERINARY CLINICAL MEDICINE
VMS	VETERINARY MEDICAL SCIENCE
VPH	VETERINARY PATHOLOGY AND HYGIENE
VPP	VETERINARY PHYSIOLOGY AND PHARMACOLOGY
VTED	VOCATIONAL AND TECHNICAL EDUCATION
WPGU	WPGU RADIO STATION
ZOOL	ZOOLOGY

10. PROBLEM SPECIFICATIONS

10.1 Research Problem Specifications

During the first quarter of 1967, 138 problem specifications were submitted to the Department for computation. The following brief descriptions of these problems have been prepared for inclusion in this report by those submitting them. T indicates a calculation associated with a thesis.

2388-71001 Chicago Circle Department of Materials Engineering. Theory of Consolidation. This is a soil mechanics problem. The effects of boundary conditions and certain special parameters that influence the stress and pore pressures in a soil mass will be investigated. The computer will be used to solve a set of parabolic and eliptical simultaneous differential equations. Analytically, these equations can be solved by Fourier-La place techniques. The La place transform can be inverted analytically. The Fourier (Hankel) transforms must be evaluated numerically. The numerical procedures require the evaluation of a quadrature between the limits of zero and infinity. The data are functions of the coordinates and of assumed material properties. (R. L. Schiffman)

2389-71002 Chemistry and Chemical Engineering. Spectrochemical Computations. Fundamental research in emission spectroscopy is being carried out in order to determine optimum analytical conditions. Following spark excitation, data are obtained in the form of lines on a photographic plate, with the line density related to the concentration of an element in the sample. Computer facilities are to be used to minimize calculations and calibrations otherwise performed manually. After determining line densities on the plate, calibration curves for the photographic emulsion are obtained by least squares procedures. Working curves, relating line density to concentration, are then determined and unknown concentrations may be calculated. (E. C. Stanley)

2390-71003 T Electrical Engineering. Dynamic Electron Multiplier. The objective of this problem is the investigation of the performance of an electron multiplier system employing the multipactor effect with crossed

static and dynamic electric fields. The computer will be used to calculate the electric field distribution inside the device from Poisson's equations by an iteration technique. The field distribution thus obtained will be used in the Lorentz equation to give the trajectories of the electrons as a function of time, and thus specify the performance of the device. The effect of a statistical distribution of electron velocities will also be considered. The result of these calculations will be used for the design of a photo-multiplier for the detection of microwave modulated light. (Schaefer)

2391-71004 Food Science. The Physical State of the Milk Proteins. The ultimate purpose of the study is to delineate the physical state of the milk proteins as they exist in their natural environment. Currently this study is divided into two phases: (1) the investigation of the binding of cations by the nonmicellular proteins, and (2) the characterization and identification of the protein components in the fat-globule membrane. In these studies it is necessary in order to interpret the results obtained tc employ various statistical treatments of the data, such as: analyses of variance and covariance, curve fitting, and propagation of errors. It is anticipated that in most cases existing programs for these purposes will be employed or modified to secure the desired information. (R. M. Whitney)

2392-71005 Nuclear Engineering. Spectrum Analysis. The computer will be used to analyze energy spectra measured by the following spectrometers: (a) bent crystal x-ray spectrometer; (b) lithium drifted semiconductor detectors; (c) surface barrier semiconductor detectors. One method of analysis which will be investigated is the "unfolding" of the system response from the measured spectra by matrix inversion or by iteration. The second method is linear and nonlinear least-squares fitting of the system response to the measured spectra. (B. Wehring)

2393-71006 T Educational Administration. Personal Educational Expenditures for Students of High Schools of High and Low Socio-Economic Status. This study will examine the personal expenditures for education for students from widely varying socio-economic status high schools. Comparisons of the difference in means for the amounts reported by the students for each category of expense related to high school attendance should indicate possible changes in school budget policy and the school curriculum. The statistical phase of this study

will include computation of the range, median, and mean for each item in the student questionnaire, their subtotals, and totals. Further computation should include a simple "t" test for independent groups of equal size drawn for each tabulated item, their subtotals, and totals, between the high and low socio-economic groups. This information coupled with preference ranking of school activities by the students should help in educational decision making.
(Melvin Lubershane)

2394-71007 T Illinois Department of Mental Health. The Psychological Adjustment of the Orthopaedic Patient. This is a study of sixty-one unilateral above the knee amputees and their controls coupled with eighteen fracture. The data were obtained in the north of England and the north of Wales. Each member of these groups was interviewed and tested with the Rorschach, The Raven Progressive Matrices, and four other tests designed to measure rigidity and flexibility. Lastly, rehabilitation and habilitation scales were employed to codify the interview. All scales and scores were agreed upon by a panel of four psychologists. The amputee group was further divided into the following sub-groups: disease, accident, below average, and above average intelligence, age, and male and female. The same designations, save disease, were used to divide the controls. Basically, the study attempts to answer two questions: How does amputation and temporary disability affect personality and can measures of rigidity and flexibility predict rehabilitation potential? Similarly, the study attempts to study the comparisons of normals who have an accident history, fracture patients, and amputees who incurred their disability through traumatic circumstances.

The formulas for obtaining the above results are as follows. Chi Square and Analysis of Variance will be used in measuring the differences between large groups. For small groups, the Fisher Exact Test will be used. Similarly Multiple Regression Analysis to determine which of the scores or which combination of scores can be used to predict rehabilitation or a habilitation potential among the major and also the subgroups.

The computer results will be used to determine if a new method of testing, based on a culture free, timeless, and open answer approach can be used in making selected predictions about amputees and normals.
(Louis M. Aaronson)

2395-71010 T Agricultural Economics. Analysis of County Participation Rates in Feed-Grain Programs. The major purpose of this analysis is to explore the feasibility of identifying the major determinants of the Feed Grain Programs' participation decision and measuring the magnitude of their effects on participation rates by analysis of aggregate secondary data. The primary analysis will be by multiple regression of time series in cross section. It is hoped that such identification and measurement of those correlates of participation which are reflected in secondary data aggregated at the county level will provide information useful in the design and administration of similar farm programs and that the method will at the same time be cheaper than survey methods while avoiding certain well-known problems of generating data by survey interview. (Rudie Slaughter)

2396-71011 T Mechanical Engineering. Optimum Gear Tooth Profiles. Recently there has been increased interest in gear tooth profiles which are distinctly different from the conventional involute profile in mathematical form and which display different gear tooth operating characteristics. Since certain non-involute profiles previously analyzed have shown definite advantages in some respects, it is thought that, for any particular criterion for gear tooth performance, there may possibly exist some optimum profile shape. It is proposed to determine these optimum shapes by a mathematical synthesis based on desired operating characteristics. The computer will be used to synthesize gear tooth profiles numerically and to analyze their properties, both with respect to established criteria. A preliminary survey has shown that these optimum profiles can be determined by solving sets of simultaneous algebraic and differential equations, for which only a numerical solution is possible. Numerical methods will also be employed to check the analytical developments of this project with those numerical results of similar, previously made analyses. Different types of known convergence techniques will be applied to sets of non-linear equations. Programming methods will be developed along with the mathematical analysis and revised according to experience. The final result sought is the numerical determination of optimum profiles in terms of dimensionless ratios from which these profiles can be made for experimentation. (Alan O. Lebeck)

2397-71012 T Physical Education for Men and Graduate PE. Motor Factors in Coincident Timing. The project consists of the measurement of the abilities involved in striking a moving target. Subjects, seated at the end of a table, see a target mounted on a v-belt moving directly toward them. The subject's task is to try to move a slider at right angles to the target direction so that a point, attached to the slider, just passes over the moving target as the latter reaches the coincidence point. The manipulation of the time the slider is in motion is the main experimental variable, which is studied by independently varying the movement distance (4 distances), the resistance to the movement (loaded or unloaded), and the velocity of the motion (fast or slow). The movement of the slider is translated, using a light and photocell system, to a 6-channel recorder, and the measures absolute error, signed error, movement time, maximum velocity, the existence of a ballistic (constant velocity) phase, and response lag, taken on each of 20 trials, are computed from the recorder paper. The experiment will use a 4x2x2 randomized blocks design (no repeated measures) with analysis of variance to determine the main (distance, rate, and resistance) effects and interaction effects on each of the measures taken. In addition, measures of intra-individual variability of the above measures will be calculated by the computer, and then subjected to the analysis of variance. Correlations on a trial-by-trial basis will be computed between the various measures. On the basis of the test results supplied by the computer, hypotheses concerning the role of motor variables in timing error can be tested. (Richard A. Schmidt)

2398-71013 Psychology. Numerical Solution of Likelihood Equations. In order to test a theory of predictive behavior in young children, it is necessary to estimate three parameters characterizing each child's tendency to use different sources of information. Maximum likelihood equations are obtained, the solutions of which give maximum likelihood estimates of the parameters. These equations must be solved by numerical methods. Concavity of the likelihood function over the three dimensional parameter space assures a unique solution. Successively smaller regions of the parameter space are obtained in which the solution must lie. The program selects a point which must lie within a sufficiently small neighborhood of the solution. (R. S. Bogartz)

2399-71014 T Agricultural Economics. An Economic Analysis of Alternative Feeder Cattle Systems. Cattle feeders of today have a problem in deciding the system to use. This project is to help solve the problem using linear programming to maximize profits. The inputs and outputs of the systems are available from research projects. LP/90 will be used after the model has been proven to work using a program written as a variation of LPG1. The different systems are combinations of three different rations, two types of cattle, and five types of facilities. There are four different objective functions used to approximate the non-linear cost functions. (Howard Peverly)

2400-71015 T Physical Education for Men and Graduate PE. Influence of Physical Training on Total Blood Volume. The study consists of determining the influence of a physical training program on total blood volume in fifteen middle-aged adults. The computer will be used to analyze metabolic data and to determine the statistical significance of the observed changes by means of analysis of variance and "t" tests. (Lawrence Oscai)

2401-71016 T Theoretical and Applied Mechanics. Thermal Buckling. Critical temperature conditions for the stability of non-uniformly heated thin plates are predicted by energy methods. Solutions for the deformations are assumed as infinite series and are used to evaluate the potential energy of the plates. The computer will be used to evaluate critical values of the parameters by performing iterative evaluations of the determinant of the potential energy matrix. The theoretical results will be used in comparison with laboratory data. (B. R. Dewey)

2402-71017 Materials Research Laboratory. Determination of Resonances in Solid Xenon. The proposed computation undertakes to answer the question: Do electron-hole resonances occur in the optical spectrum of crystalline xenon? The mathematical methods are the determinations of the complex zeroes E_i of det A(E) where the matrix A = I - G(E)V has dimension N x N, $N \leq 10$; here I is the identity, G(E) is a three-dimensional integral to be computed by Monte Carlo techniques, and V is a real, symmetrix matrix obtained by a previous computation. The zeroes E_i define the resonances sought. (John C. Hermanson)

2403-71018 Mechanical Engineering. Thermodynamic Properties. The properties enthalpy, entropy, and Gibbs function are useful in many gas dynamic and thermochemistry problems. These properties have been tabulated for many gas phase chemical compounds as a function of temperature in the JANAF tables. The coefficients for a five term fitting equation have been generated for many of these compounds. This problem specification number is requested for the initial storage of these coefficients in a protected region of disk store and the maintainances of this storage as the coefficients for new compounds become available. (L. D. Savage)

2404-71019 Psychology. Monte Carlo Simulation of Predictive Behavior by Young Children. A previous project showed that the number of trials required is too large to permit the use of a central limit theorem for Markov chains in obtaining a normal theory test of the departure of observed from theoretical curves in the testing of a theory of predictive behavior in young children. This project obtains an empirical distribution of the departures of the observed from the theoretical curves under the assumption that the theory is true, i.e., that the sequence of correct responses and errors is a two-state, first order Markov chain with stationary transition probabilities. This is done by Monte Carlo simulation of the n-subject, 75-trial experiment 1000 times using the maximum likelihood parameter estimates as the "true" values. Percentage points in the empirical distribution thus obtained will be used as critical values for approximate significance tests of the observed departures in the actual experiment from which the maximum likelihood estimates were obtained. (R. S. Bogartz)

2405-71020 Electrical Engineering. Energy Transfer to Harmonics in an Intense Acoustic Field. The aim of the research project is to determine in quantitative detail the complete neural circuitry of systems of the brain to serve as a basis for the predictive description of function, to provide information necessary to incorporate man as an effective operating unit in systems of great complexity and sophistication. The immediate aim of computer usage is to assist in quantitative neuroanatomic studies implemented by ultrasonic lesions-mammillary nuclei and associated complex of cat brain. (W. E. Spradling)

2406-71021 Psychology. Natural Language Mediation and Short Term Memory. Persons performing verbal tasks utilize networks of verbal associations in order to learn and retain material. The research seeks to clarify how persons go about this. The extent to which a person is capable of using a matrix of complex associations is a prime determinant of verbal learning and retention. Definition of what constitutes an effective associative aid for recall is a primary research goal. The computer facilities will be used primarily for the analyses of data matrices too large for efficient desk calculator computation. In addition, the computer installation provides useful flexibility in terms of forming composite scores, frequency distributions, etc. Three and four factor analyses of variance involving one and two repeated measures will constitute the primary statistical operations. (Adams)

2407-71022 Psychology. Interpersonal Attraction. The project is in the general area of personality and social psychology. A series of studies will investigate the effect of a variety of stimulus and personality variables on the dependent variable of interpersonal attraction. The data are collected in the form of paper and pencil responses by human subjects. Their responses will be analyzed principally by the use of various analysis of variance designs. Group means and standard deviations and occasionally correlation coefficients will be obtained. (Clore)

2408-71023 T Sociology. Working Class Adolescent Educational Aspiration. The proposed research is an attempt to define and measure the correlates of working class adolescent educational aspiration and achievement levels which are higher than the general levels of the working class as an aggregate. The theoretical approach of the proposed research is to concentrate on correlates which are class specific or, in other words, are differentially related to aspiration in class groupings. This research is relevant to the sociological areas of interest of stratification and social mobility, education and adolescence. The major research design element is comparative and will consist of dividing the sample into social class categories, and within each class category, comparing the high and low achievers/aspirants on a number of variables. The relationship of achievement/aspiration to these variables is expected to differ in the different class categories.

Additional controls will be student academic aptitude, the homogeneity of the class composition of schools attended, parental aspiration, and peer aspirations. The data to be utilized in this research are a 10% subsample of males of the sample survey conducted in 1960 by Project TALENT. This student reported data were collected from 9th, 10th, 11th, and 12th grade students. The subsample is a representative sample of the U.S. in school population in 1960. The large N of the subsample (10,000+) will allow the use of a number of controls with contingency table analysis. Because of the nominal scale of much of the sociological data, contingency table analysis is required, and a large N can provide the necessary cell N's for the various matrices. Data on the attended schools' characteristics such as indicators of ethnic and class composition reported by school personnel and follow-up data collected from student respondents a year after their class was graduated from high school will be matched with the original student data. The programs to be utilized are from the SSUPAC library. Programs to be used will vary according to the nature of the specific variables. However, frequency counting, measures of association, correlation, transformations, and analysis of variance are programs that are anticipated to be used. (Haurek)

2409-71024 Astronomy. Shape of Galaxy. There are two small galaxies in the immediate neighborhood of our galaxy. Gravitational interactions must occur, and it is desired to find the nature of the effect of these galaxies on our own galaxy. Our galaxy will be distorted in the outer parts (beyond the position of the sun), and the nature of the distortion depends strongly on the mass model chosen for the galaxy. Previous calculations (by hand) found the distortions for a point-mass galaxy and a spheroidal galaxy with equatorial radius equal to the sun's distance from the galactic center. The disadvantage to these models is that the mass beyond the sun must be neglected. This outer mass will have a strong restoring effect, causing a force which counteracts the disturbing effect of the two external galaxies. A model is proposed in which the galaxy is represented by a disc surrounded by rings which at any time are tilted to the plane of the disc in such a manner that the maximum perpendicular distances follow a power law. The disturbing bodies act on an initially flat galaxy and cause a small distortion which is then fit by least squares to the best power law. With the exponent thus

determined the self-attraction of the outer part of the galaxy can be found. This self-attraction together with the attraction of the disturbing bodies then yields a new shape for the distortion and therefore a new exponent. Thus the shape of the galaxy at any particular time can be found. These results can than be compared with observations of neutral hydrogen in the galaxy, since the observations do show a systematic deviation of hydrogen from the galactic plane. (E. S. Avner)

2410-71025 T Nuclear Engineering. Spatially Dependent Neutron Spectra in Heterogeneous Lattice. The spatially dependent neutron spectra in a reactor of a hexagonal lattice of coolant channels in a homogeneous fuel-moderator medium is desired. The neutron direction dependence is represented with an expansion in spherical harmonics. Two energy regions are studied: The epithermal neutrons and thermal neutrons. An energy damping factor relates the distributions in each energy region. Computational methods are needed for double integrals with fixed and variable limits. The numerical method employed is based on Simpson's 1/3 rule. Also the solution of a set of inhomogeneous linear equations is found using the computer. All data which specified the problem come from the physical system. The computer results will ultimately yield the neutron distribution for thermal energies. (Luoma)

2411-71026 T Psychology. Cross-Cultural Comparison of Children's Work Roles. This cross-cultural study investigates relevant dimensions of children's work roles, the relation of children's duties to those of adults, and the influence of ecological factors on the division of labor. Fifty-eight selected societies, described in the Human Relations Area Files, yielded an average of twenty tasks per society which could be rated on ten relevant scales. Data for the sample societies on twenty ecological variables were taken from the Ethnographic Atlas published in the Journal of Ethnology. Task scales will be analyzed by the computer giving the distribution of rating variables, joint probabilities, and measures of association such as χ^2, λ, or φ coefficients in terms of society, task, age, and sex breakdowns. After internal analysis, indices of cultural dissimilarity, derived from median and distributional differences of work role variables, will be

calculated. The relation of such indices to ecological variables will then be analyzed by the computer using methods similar to the above. This analysis should result in delineation of factors influencing childhood tasks and initiation into the adult work world. Socialization of work roles can then be related to other aspects of the total socialization process. (Barbara Baldridge)

2412-71027 Chemistry and Chemical Engineering. Reaction Parameter Studies. Computer time will be used to calculate reaction parameters (i.e., rate constants, product ratios, species' concentrations, activation energies, entropies, and enthalpies) for reactions of organic compounds. The programs used generally provide least squares fits to appropriate linear expressions for the phenomena being investigated. The data are generally obtained through the use of applicable chemical analysis methods (e.g., vapor phase chromatography, acid-base titrimetry, or ultra-violet and visible spectrophotometry). (S. G. Smith)

2413-71030 Physiology. Temperature Regulation of Periodical "17-Year" Cicadas. Insects respond to the thermal stresses of their habitat by selecting locations where temperatures are tolerable. Changes in location which alter the direction of heat flux into the animal occur whenever the internal temperature of the insect rises above or below certain set-point levels. The specific problem dealt with here will compare these set points among three closely related "17-year" cicadas sharing nearly the same habitat. To avoid competition, these species apparently utilize different parts of the day for courting, feeding, and so forth. As a consequence they differ in their thermal tolerance. This study should clarify the knowledge of adaptation to temperature stress and effect of changes in temperature upon critical rate processes of insects. SSUPAC programs will be used to obtain statistical analyses of the responses of the three species of cicadas to temperature. The computer will be asked to make calculations of means, variances, and correlation coefficients of the various temperature and temporal parameters measured. (J. E. Heath)

2414-71031 T Library Science. Comparison of Computer-Based Instruction and the Conventional Lecture Method in Library Science. The purpose of this study is to explore the possibilities of using computer-based instruction as a medium for teaching the use of the library to undergraduates. Comparisons of results will be made between the experimental group using the computer-based teaching system PLATO (Programmed Logic for Automatic Teaching Operations) and the control group learning by the traditional lecture method. This study has been conducted for three semesters--Fall 1965, Winter 1966, and Fall 1966. Statistical analysis will be made between the performance of the two groups in order to determine if computer-based instruction is just as feasible, or more so, than the conventional lecture method. (Marina E. Axeen)

2415-71032 T Mechanical Engineering. Desalination: Radiation Integrals. Integration of monochromatic absorption coefficients for thermal radiation will be carried out numerically for the radiation distribution of radiators at various temperatures, yielding total absorption coefficients. In addition, an integral describing the effect of radiation striking a surface at directions other than the normal to the surface will be evaluated. The latter integral involves functions of the inverse sine. Standard techniques of numerical integration will be used in the evaluation of both integrals. Initial input data (monochromatic absorption coefficients) will be data for pure water as obtained from the literature. Later data will be for sodium chloride-water solutions of various concentrations, as measured in the Heat Transfer Laboratory of the Mechanical Engineering Department. (E. F. Janzow)

2416-71037 T Theoretical and Applied Mechanics. Attenuation at Ultrasonic Frequencies. A set of nonlinear differential equations, describing the attenuation of vibrations at ultrasonic frequencies, has been reduced to a set of cubic algebraic equations. The computer will be used to solve the set of cubic equations. The number of equations in the set will be from 50 to 100 cubic equations. The standard formula for obtaining the roots of a cubic equation will be used. A number of parameters in the equations will be varied to observe their effect on the solutions. The parameters will be

chosen so as to correspond to experimental results obtained in attenuation measurements of ultrasonic waves. (Thomas J. Bander)

2417-71038 T Nuclear Engineering. Nuclear Pumped Lasers. Excitation to provide inversion population in gas lasers can be provided through interaction of nuclear radiations with a lasering medium chosen in this case as a gas. Equations governing the transient and steady states of the populations of excited atoms can be derived, relating the input power (in the present case the energy lost by alpha particle slowing-down through a gas) to the density of population of the various excited states and the laser power output. Parameters such as the geometrical dimensions of the gas containers, the pressure and composition of the gaseous mixtures, the input power can be varied. In the prediction of laser wavelength and power output, these theoretical studies go along with experiments performed at the University of Illinois Nuclear Reactor. (J. C. Guyot)

2418-71039 T Nuclear Engineering. A Ball-of-Fire Laser. This problem has to do with a laser which operates in the ignited or ball-of-fire mode of gaseous electrical discharge. Its large area cathode makes it attractive for direct coupling to nuclear heat sources. In this problem, equations will be derived and solved giving both the gross plasma properties, such as number density, electron temperature, etc., and detailed lasering media properties, such as state population profiles. It is anticipated that this will involve solutions of linear and non-linear algebraic and ordinary differential equations. Finally, these results will be compared with experimental measurements on a laser tube which has been constructed for this purpose. (J. E. Herceg)

2419-71041 Electrical Engineering. Ionospheric Z-Trace Analysis. The project involves the analysis of data obtained when radio-wave energy is propagating in the ionosphere in the Z-mode. The computer will be used in ray-tracing analysis and in the determination of the amplitude of the Z-mode assuming it arises through coupling at the reflection height of the θ-mode. Both these computations involve the numerical integration of a set of simultaneous differential equations. The Z-mode data were obtained

from radio propagation experiments carried in rockets fired from Wallop's Island, Virginia. The computer results will be used as a basis for the interpretation of these data. (P. Monro)

2420-71042 Chemistry and Chemical Engineering. Three-Body Planar Reactive Collisions. The problem investigates the trajectory of three-atom collisions in which chemical reaction may occur. A Runge-Kutta numerical integration procedure is employed to integrate the classical equations of motion for the system as the trajectory advances through the collision. A semi-empirical interaction potential is employed in the problem. The program, with initial collisional parameters selected as random input data, returns information as to the energy and momentum changes undergone by the system during collision and/or reaction. The output is subsequently averaged over the initial set of input parameters chosen. The output will be examined to determine whether or not an adiabatic principle governing rotational energy transfer is in operation. If so, the theoretical treatment of reaction rates and cross-sections in two dimensions may be advantageously simplified. (R. V. Serauskas)

2421-71043 T Zoology. The Variation and Systematics Within the Salamander Genus Pseudoeurycea (Plethodontidae). The proposed research problem is a detailed analysis of the specific and geographic differentiation within the salamander genus Pseudoeurycea (Plethodontidae). Basic SSUPAC routines such as the t-test, analysis of variance, transformation, and the analysis of correlation and regression will be used to describe and test differences within and between population samples. The measurements used are fifteen linear measurements taken from the preserved specimens using dial calipers accurate to within .01 mm. (Macreay Landy)

2422-71044 T Educational Administration. Verbal Interaction Analysis in the Bolivian Classroom. The overall project is a feasibility study determining the acceptance and application of a strategy of self-assessment in a Latin culture. The data were obtained in a series of classroom observations, utilizing a systematic assessment instrument. The computer will give two types of information: (1) percentages of various types of

teacher-pupil interaction; and (2) a likelihood ratio which will determine whether the frequency distribution in two or more matrices are the same. The computer results will be used to help determine the usefulness of self-assessment strategies in a Latin culture. (Anderson)

2423-71045 Architecture. Economy in Building Structures. This study will be concerned with the economy which will result from optimum framing systems for building. The study will begin with timber as a basic framing material. Pinned end supports with uniform and concentrated loads will be considered initially. Mathematics will include simultaneous equations, roots of equations, evaluation of integrals, and differential equations. (Linwood Brightbill)

2424-71046 T Civil Engineering. Probabilistic Analysis of Dissolved Oxygen - Biochemical Oxygen Demand Relationship in Streams. The classical Streeter-Phelps equation for the stream assimulative capacity assumes constant coefficients in the differential equation

$$\frac{dD}{dt} = k_1 L_a e^{-k_1 t} - k_2 D.$$

The literature on stream pollution surveys bears ample evidence to show that the coefficients k_1 and k_2 take a range of values. The scope of this investigation is to treat the coefficients as random variables. The probability density functions of the random variables will be determined by plotting histograms for k_1 and k_2 using the published stream survey data. The differential equation with variable coefficients will be solved by numerical methods. Knowing the functional relationship between the three random variables D, k_1, and k_2, and the probability density functions of k_1 and k_2, it is possible to determine the probability distribution of dissolved oxygen deficit at any section of the stream by employing the principles of transformations of random variables. This information could then be used to determine the probability of violating stream standards, the mean and model values of the dissolved oxygen deficit, and other statistics of interest. Combining the probabilistic Dissolved Oxygen-Biochemical Oxygen Demand Relationship model proposed to be developed

in this study and the first order Markov model for stream flow developed by Loucks and Lynn, a more general probabilistic model for the dissolved oxygen unit distribution in the stream could be developed. (V. Kothandaraman)

2425-71047 Mechanical Engineering. Analyses of Power Systems. The major activity includes numerical simulation of power systems. An instance is a computer engine system to determine optimum choice of system parameters. Data will be gathered from known literature or from actual engine tests. Curve fitting, integration, and differentiation will be main uses for the computer. Hopefully a completely analytic solution can be found which describes the power system, and simple numerical alteration of the system parameters will predict the most effective design. (H. H. Korst)

2426-71048 T Psychology. A Multidimensional Analysis of Preference. This research problem involves the use of several different techniques for the scaling of preference in multidimensional vector spaces. Several techniques which have previously appeared in the literature, such as multidimensional scaling, vector preference scaling, and factor analytic techniques will be employed, as well as a new and as yet untried method. (Appelbaum)

2427-71049 Chemistry and Chemical Engineering. Asymmetric Rotor Spectra. It is desired to calculate the spectrum to be expected of a rigid asymmetric rotor undergoing a transition between the electronic states, in which the moments of inertia may be different. All the populated energy levels of the ground and excited states are calculated from assumed input values of the moments of inertia by diagonalization of the Hamiltonian matrix, calculated in the symmetric rotor basis. The intensities of each of the contributing lines are then calculated from the appropriate selection rules and added to the overall contour with a gaussian shape. The resulting spectra are then plotted and compared with the experimental spectrum to obtain the correct rotational constants. (Lombardi)

2428-71050 State Water Survey. Urban Hydrology Project. The broad objective of this study is to gain insight into the effects of watershed and rainfall characteristics on runoff from urban areas. An inventory of Illinois engineers has shown the rational method to be in wide use for the design of urban storm drainage facilities. This and other more recently proposed methods for computing runoff peaks or complete hydrographs will be tested on Boneyard Creek at Urbana, Illinois. This is a 3.7 square mile urban basin that has been gaged since 1950. A time-area diagram, percent imperviousness, stage storage relationships, and unit-hydrographs have been developed for the Boneyard, and if necessary there is a possibility of further instrumentation on certain subareas. Effects of variable rainfall on the basin will also be considered. Recently, a considerable amount of urban rainfall-runoff data was secured from Johns Hopkins University. It is hoped that through the use of a digital computer, these additional data can be used to confirm a design methodology. (M. L. Terstriep)

2429-72010 Civil Engineering. Influence Charts for Moments in Railroad Rail. One of the prime considerations in the design of a locomotive or freight car is the moments and resulting stresses that the new piece of railroad equipment will impose on the supporting rail. Of equal importance to a railroad is the checking of moments and stresses in a rail when subjected to various combinations of various wheel loads at various speeds. In the past, these moments have been investigated by using a general influence line which was derived by treating a rail as if it were a beam on an elastic foundation. To use this influence line parameters which represent the properties of the specific track structure and the configuration of wheel loads under consideration must be calculated. Any change in a parameter such as a shift in the position of the wheel loads will require recalculation of the parameters. The purpose of the proposed research is to facilitate the finding of moments in rail. This would be accomplished by using the computer and taking the general equation of a beam on an elastic foundation and solving by Newton's approximation for the distance from the point at which the moment is to be found to another location which yields a specific moment at the former point. By repeating

this calculation for various track parameters, data describing an influence chart may be generated. These data would then be plotted on the CalComp plotter to yield the final chart. To use the chart to find moments one needs only draw the wheel configuration to a reduced scale and then superimpose it on the influence chart. A small number of simple calculations will give the moment. Any changes in parameters are accomplished by shifting the scale drawing of the wheel configuration on the chart and by repeating a few simple calculations. (Gregory Martin)

2430-72022 Psychology. Attention in Infants. The research will include three experiments on visual attention in infants. Infants' visual fixations to patterns of moving dots will be recorded by an observer. Both the amount of information contained in the dot patterns and the past experience with the dots will be manipulated. These experiments are designed to examine the proposition that infants will prefer an intermediate amount of information, and that as experience with informational stimuli increases they will come to prefer more and more information. The computer will be used to do the statistical analyses of the data. Each experiment will include three analyses of variance of fixation times. (Leslie B. Cohen)

2431-72023 Zoology. Simulated Animal Populations. The project is designed to generate the behavior of gene frequencies in simulated populations under various parameters such as population size, reproductive structure, and individual genotype and phenotype fitness valves. Generation i + 1 will be generated from generation i by calculating the expected phenotypic frequencies and then using a random number generator to produce a normal deviation from the expected frequencies. The starting data will come from theoretical considerations and published accounts of actual animal populations. The results from this study will be used to check published work, to give insight into population behavior for the researcher, and to give classroom examples for a difficult area of student study. (Tenczar)

2432-72024 Chemistry and Chemical Engineering. Quantum Mechanical Calculations on Large Molecules. The nature of the bonding in several large inorganic systems will be investigated quantitatively. Large molecules and ions will be included in this investigation, which is based on the approximate Molecular Orbital Method. It is hoped that this investigation will set the precedent for investigating the bonding in inorganic molecules and lead to a general theory of bonding in Inorganic Chemistry. The data are obtained from infrared and ultraviolet-visible spectroscopy. The computer will be used to compute the familiar molecular orbital quantities, e.g., orbital energies and charge densities, which will then be related to the molecular properties. (A. F. Schreiner)

2433-72025 T Theoretical and Applied Mechanics. Anisotropic Plates and Beams. The problem to be investigated is the determination of the physical properties that will result in minimum deflection of various fiber reinforced plates and beams subjected to various lateral loadings. The method to be used in each case to solve the defining differential equations is the method of Navier, which makes use of a double trigonometric series. (Tod Jester)

2434-72026 State Water Survey. Raindrop Size Analysis. Over the past several years, over 20,000 raindrop size distributions have been obtained in natural rains. Most of the analyses of these data have been completed. However, from time to time, new ideas for use of these data arise. New correlations of these data with other parameters may be desired, new combinations of the data may need to be tested, or new parameters may need to be calculated from the data. Also, this problem specification will be used to re-process data whenever errors are found and corrected. In general, programs developed under 2D016, 4D019, and other problem specifications will be used, occasionally with some minor modifications. (E. A. Mueller)

2435-72033 Geology. Crystal Structure Analysis of Aragonite. The research will involve an accurate and complete determination of the crystal structure of the mineral aragonite, an important relatively low temperature-high pressure phase of $CaCO_3$. The methods to be used in the structure analysis are: Lorentz-polorization and absorption corrections of X-ray intensity data; Paterson synthesis involving Harker sections; Fourier synthesis; and least squares refinement of atomic parameters, including anisotropic thermal motion parameters. These computations will be carried out using existing programs. The data were collected by standard visual estimation of the intensities of the diffraction spots on diffraction films. Multiple film packs were used. The computer results will be used to determine accurately the atomic positions in aragonite, and to refine the parameters of this structure. (D. M. Henderson)

2436-72040 T Physical Education for Men and Graduate PE. Effects of Different Amounts of Training on Fitness. The problem involves the determination of the effects of zero, three, and five day per week training on selected tests in cardiovascular, motor, and respiratory fitness of adult men, twenty-five to fifty years old. Approximately thirty-six men from the Champaign-Urbana community were divided into three groups. These men voluntarily registered in the Adult Fitness Program at the University of Illinois. The men were assigned to the following groups for a five month training program: Group A, running and calisthenics 3 days per week; Group B, running and calisthenics 5 days per week; Group C, control, normal activity only. The subjects are being tested prior to, during, and at the conclusion of a five month training period extending from November, 1966, through March, 1967. Cardiovascular, motor, and respiratory tests are given at T-1 (October). Only the cardiovascular tests are given at T-2 (December), and T-3 (February). All tests are given again at T-4 (April). Gross cardiovascular fitness is measured by the heartometer measurements of systolic amplitude, obliquity angle, area, and pulse rate. Selected motor tests include the agility run, balance tests, strength tests, chin-dip-vertical jump, flexibility tests, and a mile run for time. Respiratory tests include vital capacity residual and breath holding. The three groups will be compared on each test item using the analysis of covariance on each of the last three testing periods, T-2, T-3, and T-4. A significant difference between means will be tested at the .05 level. (Larry Gettman)

2437-72041 T Materials Research Laboratory. Optical Constants of $AuAl_2$ by Reflection. In this project, the Fresnel equation is employed to study the optical constants of solids by using an incident polarized light and measuring the reflectivity as a function of incidence angle. The data will be plotted by the computer, as follows: (1) Given eight sets of incidence angles with corresponding reflectivities, absorption coefficients range from 0 to 5 with step 0.05. Curves of constant reflectivity will be plotted as refractive index vs. absorption coefficient. (2) Given five sets of incidence and absorption coefficients from 0 to 5 with step 0.05, the Fresnel equation is reduced to reflectivity as a function of refractive index. Curves representing reflectivity vs. refractive index are then plotted. (Han C. Shih)

2438-72047 T Economics. Production Functions and Technological Change. The problem involves estimation and simulation of production functions. Both hypothetical and census data will be used. The statistical devices which will be used include multivariate analysis, least squares, maximum likelihood, and mathematical programming methods. Various statistical tests on the results will be conducted. Numerical approximation to the solution of high order polynomials and of sets of simultaneous equations will be used. The final result will be a comparison among several important production functions, based on the statistical tests result and the plausibility of economic reasoning. (S. F. Chu)

2439-72048 Theoretical and Applied Mechanics. Buckling of Cylindrical Shells Due to Axial Load. This buckling problem is an eigenvalue problem, the eigenvalues being the circumferential and longitudinal waves, m and n, in the buckled configuration. A cubic equation involving m, n, and a load parameter Φ is obtained. This equation is solved for Φ for each m and n, and the minimum ϕ is retained as the solution. The coefficients of the cubic equation are determinants. The computer will be used to evaluate these determinants and solve a cubic equation by iteration. (J. L. Ford)

2440-72049 T Nuclear Engineering. Study of Electron Motion in Electric and Magnetic Fields. The motion of electrons in electric and magnetic fields is to be studied for the purpose of studying the feasibility of a crossed field photomultiplier which would have a sub-nanosecond rise time. The differential equations governing the electron motion have been solved by standard techniques yielding transcendental equations. The computer will be used to solve these equations for varying field conditions to find the optimum condition for photomultiplication with minimum rise time. (Donald J. Leverenz)

2441-72050 T Electrical Engineering. Probability of Stability of Random Matrices. Given a linear system of n variables, described by its n x n matrix, it is desired to know the probability that the system will be stable, as a function of its degenerateness (percentage of zero entries in the matrix). Computer solution by random sampling is expected to give results for systems up to 10 x 10, in various degrees of degenerateness. Matrices will be generated from both gaussian and rectangular distributions. In initial work, diagonal elements will be negative, representing stable system components. Each matrix will be tested for stability by the method of Hurwitz, which checks the sign of determinant-evaluated sub-matrices. Knowledge of how many matrices are rejected at each step of the method may allow determination of how the probability of stability drops with n. Graphs of probability of stability versus degenerateness for fixed n, and of probability of stability versus n for fixed degenerateness, will be constructed. It is hoped that these contructions will allow extrapolation to higher order systems, and provide suggestions for direction of future efforts. (Mark R. Gardner)

2442-72051 Educational Psychology. Project Upward Bound. Project Upward Bound is a federally funded program designed to ameliorate the adverse effects of economically, educationally, and culturally disadvantaged backgrounds upon secondary school students. The eventual goal is to motivate and adequately prepare such students for college.

Sixty-four students from the East St. Louis, Illinois area, all meeting the poverty criteria of the Office of Economic Opportunity,

were selected on the basis of academic potential and current deficiencies. These students underwent an eight-week residential program on the Urbana campus in the summer of 1966 and are currently involved in a special academic-year tutorial program in their home areas. The residential and tutorial programs will continue through June, 1968, with a longitudinal follow-up program to continue as a check on the program's success.

Batteries of academic achievement, aptitude and personality tests were administered to the students at the initiation of the program. Periodic re-assessments are planned. Among the uses planned for computer analyses are development of academic prediction formulas, periodic pre-post comparisons of control and project students, assessments of relationships among different types of instruments (e.g., language-non-language aptitude tests), and determination of progressive changes, if any, on personality instruments such as the Michigan State motivation scales. (Dr. J. D. Boney)

2443-72059 Civil Engineering. MOTRAN - Matrix-Oriented TRANslator. There has been increasing interest in the use of computers in the civil engineering curriculum. The MOTRAN (Matrix-Oritented TRANslator) system is being developed to assist in the instruction of matrix methods of structural analysis. One of the greatest obstacles to the effective instruction of matrix solution methods is the excessive hand calculations required of the student. The primary purpose of the MOTRAN system will be to eliminate the laborious calculations while still requiring the student to specify the correct sequence of operations in the solution procedure.

With MOTRAN, a combination problem-oriented and algebraic language, it will be possible to solve a structural problem using any classical solution method. Individual statements will be written in an essentially free-form format. The matrix and structural operations processed by the MOTRAN subroutines stored on tape will be combined in any desired fashion in a single statement, the end result of which could be either added to a submatrix of a larger array stored on a disk, or equated to another compatible array and stored on the disk. (John Leonard)

2444-72060 T Materials Research Laboratory. Calculation of Lattice Sums. In order to make theoretical calculation of the elastic constants and potential energy of calcite, it is considered to be a good approximation to employ either Born theta function transformation method or Evjen's direct summation method. Both methods will be used to compare them with the experimental results later. For the first method, the numerical calculations of exponential integrals, and the Gauss' error functions will be needed. For the second direct method, the geometrical calculations of the lattice sums in many hexagonal cells of gradually increasing size are necessary. The crystal structure of calcite is divided into several neutral groups to get the rapid convergent lattice sums in both cases. (Hiroyuki Kaga)

2445-72065 Electrical Engineering. G-20 to CalComp Conversion Routine. It is proposed that the 7094 be used to process data cards from the G-20 computer facility to produce CalComp graphs for users of the G-20. The program uses a table-lookup method. The data consist of cards punched by G-20 users when they desire CalComp plots. The purpose is to give the G-20 facility CalComp capability while their own CalComp software is being developed. (Roger A. Vossler)

2446-72070 T Psychology. Propositional Control and Inter-Trial Interference. This experiment required subjects to read eighty pairs of sentences one pair at a time. One member of each pair always contained a correct word. Whenever subjects read that sentence, the experimenter would respond by saying "Good". Between every sentence pair, subjects were given a second task to do. The purpose of the study was to determine whether the second task would interfere with subjects' becoming aware of what the correct word was and whether subjects would learn to select the correct word even when they were unaware of what the correct word was. The data for each subject included a set of measures of degree of awareness of the correct word and selection frequency of that word over the course of learning. The computer will be used to analyze these data by means of analyses of variance, and simple and multiple correlational analyses. The computer results, in the form of significance tests of the means, simple correlations, and multiple correlations, will be used to assess whether learning occurred with or without awareness. (Ralph Lubitz)

2447-72074 T Physical Education for Men and Graduate PE. The Metabolic Cost of Selected Gymnastic Routines. The purpose of the study is to determine the metabolic cost of selected gymnastic routines. The data are being collected with a volumetric device called the Kofrangi-Michaelis Respirometer. Collection bags are attached to this apparatus for use in gas analysis. Energy cost work involves volume readings as well as gas analysis readings. Energy cost of the gymnastic routines will be expressed in gross and net terms. The digital computer will be used to check the numerous metabolic calculations necessary. (Sidney B. Sward)

2448-72076 Office of Research in Medical Education. International Medical Student Study. The International Medical Student Study is a study of the performance of selected groups of medical students (from five countries) on medical school achievement tests. The same examination is to be administered to students in the cooperating institutions in the five countries and their performance on the total and on various sub-tests will be compared, employing analysis of variance techniques. Individual test scores will be obtained on the total and on various sub-tests as a basis for reports to individual students; in addition, standard test statistics and standard item data will be obtained for the total test and each sub-test. These data will be used as the basis of comparison among the five experimental populations. (Sund)

2449-72077 T Agricultural Engineering. Analysis of Timeliness in Soybean Harvesting. The objective of this project is to obtain an economic cost of untimely harvesting of soybeans. Such information is needed to optimize the selection of field equipment. Computer time will be used for data analysis. The Analysis of Variance program in SSUPAC will be used for tests of significance. Data used represent pre-harvest loss, cutterbar loss, separating and threshing losses, and bin yields. (D. R. Hunt)

2450-72081 Civil Engineering. Seepage Through a Porous Medium. The research problem consists of the determination of the flow characteristics of water through a soil medium. The soil medium may be multilayered, i.e., layers with different coefficients of permeability, and may as well have different coefficients of permeability in the vertical and horizontal directions of each layer of soil. The flow of water underneath masonary dams, through earth dams, and into cofferdams will be analyzed. The method used to effect a solution will be a relaxation procedure to solve Laplace's equation

$$\nabla^2 h = 0$$

where h is the total head and equal to the sum of the pressure head and the elevation head. The computer output will consist of the total flow through the soil, critical hydraulic gradients, and, in the case of a masonary dam, the uplift pressure distribution along the base of the dam. The output will be used to study the design of different structures and to modify the structure so as to obtain the best design. (T. K. Liu)

2451-72090 T Agricultural Engineering. Bed Scour Below Cantilever Pipes. A laboratory model of bed scour below a cantilevered pipe outlet is in progress. The digital computer will be used primarily to reduce raw data and compute dimensionless parameters. Depths of scour and fill will be measured at 1 or 2-inch intervals over the bed. The bed measures 4 by 6 feet. The volume of scour will be computed with the borrow-pit formula used in earthwork calculations. It is desirable to use the computer since each run will produce 500 or more data points, and there are over 50 runs planned. The large number of runs results from varying tailwater over the bed, pipe elevation, and flow rate. Also approximately seven dimensionless parameters will be calculated for each run. (John D. Hendrick)

2452-72111 Chemistry and Chemical Engineering. High Resolution Nuclear Magnetic Resonance Studies. The dynamic structure of liquids will be investigated by measuring the relaxation times using the fast adiabatic passage nuclear magnetic resonance method. There are two stages of the project considering the use of the computer. First, the experimental conditions will be simulated in a computer experiment in order to obtain information on the capabilities and limitations of the fast adiabatic passage methods to yield quantitative results. In the second phase of the project, a computer program will be written to analyze the experimental data for different systems investigated. The experimental oscilloscope patterns will be digitized and analyzed by the program to yield the relaxation times. The mathematics involves standard matrix algebra, non-linear least-squares line-shape fitting methods, use of convolution integrals, etc. (J. Jonas)

2453-72112 Mathematics. Finite Planes of Order 9. This project will attempt to produce all non-isomorphic planes of order 9 by reducing the list of non-isomorphic latin squares of order 8, and using this reduced list as possible starts in generating the non-isomorphic planes. Since there are 1,676,257 non-isomorphic latin squares of order 8, it is necessary to use a machine to determine which squares can be completed to a plan, and to perform the completion. (J. W. Brown)

2454-72113 Industrial Administration. DYNAMO System for Industrial Dynamics Simulation. DYNAMO is a special purpose compiler for translating and running simulation models of the sort used in industrial dynamics. The language has been designed to be easily understood by the uninitiated and quickly learned by the novice programmer. In general, the models are continuous representations of the real world. There is a great similarity between DYNAMO and analogue simulations, although the two languages are very different. Randomness may be included but in a continuous manner. The mathematical process being carried out is a non-simultaneous solution of a set of simultaneous ordinary differential (integral) equations. Integration is by rectangular techniques using the left corner. (Ken Panza)

2455-72114 Mechanical Engineering. Evaporator Response. Knowledge of the response characteristics of a refrigerant evaporator can be useful: (1) in predicting the behavior of the evaporator when changes occur in the refrigeration load or refrigerant flow rate supply, and (2) in determining the transfer function so that a control stability analysis can be performed on the evaporator-expansion valve feedback loop. A technique was developed for obtaining a photographic record of the motion of the mixture vapor transition point in the evaporator by utilizing the light scattering properties of a liquid-vapor mixture. The data contained on each frame of the photographic record include the instantaneous position of the transition point and the corresponding time, which is indicated by an electric timer. Thus, a detailed study of the motion of the transition point can be made by observing successive frames of the photographic record. The data contained on this photographic record will be punched on data processing cards to facilitate additional data reduction and analysis. (J. F. Wollschlager)

2456-72115 Chicago Circle Department of Materials Engineering. Computer-Aided Design System. The problem is to develop a new computed-based system with an appropriate problem-oriented language which will provide for an integrated approach to computer-aided design in civil engineering. Three activities are proposed: (1) To develop soil engineering algorithms to: (a) calculate stresses in layered systems; (b) compute settlements using a three-dimensional model; and (c) calculate progress of settlement. (2) To extend the above algorithms for the above and for STRESS to account for the soil-structure interaction. (3) To incorporate both of the above into a general problem-oriented language and system. Finite difference and finite element techniques will be used along with problem generator languages developed by S. J. Fenves. (R. L. Schiffman)

2457-72116 Electrical Engineering. Rocket Data Processing. Under sponsorship of the National Aeronautics and Space Administration, the Aeronomy Laboratory of the Electrical Engineering Department launches about six Nike Apache rockets per year for the investigation of the ionosphere. This problem involves a program for obtaining Faraday rotation rates and differential absorption rates from the data obtained from the rocket

experiments. These rates are then used for the determination of electron densities and collision frequencies in the ionosphere. (Seino)

2458-72117 Department of Computer Science. Critical-Race Free, Minimal Time, Minimum Variable State Assignment. For any given flow-table specifying an asynchronous sequential machine, a state assignment having the following features is commonly desired: (a) free of critical races; (b) minimal transition time - that is, the maximum time for any transition between two stable states is the time required for the slowest state variable element to change; (c) minimum number of state variables. In general, there may be more than one solution. It has been shown that to satisfy (a) and (b) in the above assignment, it is necessary and sufficient to require that: (1) every dissociated pair of transitions in an input column of the original flow-table or (2) every transition and dissociated stable state in an input column of the table be distinguished by at least one state variable in the state assignment. This program implements an algorithm which produces all solutions to the problem by satisfying the necessary conditions. (F. E. Hohn)

2459-72118 T Educational Administration. The Effects of Staff Feedback on Administrative Performance. The purpose of this investigation is to study the effects of feedback given to elementary school principals from their respective staffs on possible changes in teachers' perceptions. This study will utilize a pre- and post-test measurement along two dimensions. One is a measure of a staff's evaluation of certain "actual" administrative occupational characteristics. The other dimension is a measure of what a staff considers to be as an "ideal" elementary school principal. Feedback will only be given to the experimental group of administrators. Eight schools will compose the sample. The basic statistical analysis will consist of a series of t-tests. A post-test will be used to measure any subsequent changes in teachers' perceptions for those teachers in both the experimental and control groups. (Jason Martin)

2460-72119 T Materials Research Laboratory. Complex Molecular Orbital Moment Integration. In calculating the intensity of optical spectra of transition metal complexes, the molecular orbital of the system is usually

obtained from linear combination of atomic orbitals. Hence, the transition moment involved is usually a two or three center integral. This research will use Slater type and/or Gaussian type atomic orbitals to calculate the transition moment of a complex in a static configuration. The vibration pertubation will be added then, and the vibronic intensity of the symmetrically forbidden transition bands will be calculated. The result will be compared to the experimental data for optical absorption intensities of crystalline transition metal compounds. (Dean Huang)

2461-72120 T Physics. Determination of Effective Helium 3-Helium 3 Interaction. The problem to be considered is the determination of the effective Helium 3-Helium 3 interaction in dilute mixtures of Helium 3 in Helium 4 at very low temperatures ($\lesssim 1^{\circ}$ Kelvin). It is to be done phenomenologically by first expanding the interaction in powers of the momentum squared:

$$V(k) = \sum_{i=1}^{n} a_i k^{2i} \quad .$$

Theoretical expressions for the transport coefficients are then determined from this V(k), resulting in a set of bilinear (in the a_i) expressions which are equated to experimental values of the transport coefficients. Tentatively, n is taken equal to the number of experimental values available. Because of both theoretical and experimental uncertainties, the solutions of this set of equations will likely be complex whereas, physically, the a_i should be real. Therefore, the 7094 library subroutine MIN1 will be used to find local minima of the quantity:

$$f(a_1 \ldots a_n) = \sum_{j=1}^{n} (C_{Ej} - C_{Tj})^2 / C_{Ej}^2 \; ; \; C_{Tj} = C_{Tj}(a_1 \ldots a_n)$$

where C_{Tj} are the theoretical expressions for the transport coefficients and C_{Ej} are the experimental values. At the moment, n = 5; it may be expected to increase as more experimental numbers become available. (Charles Ebner)

2462-72121 Economics. Reciprocity in Diesel Purchases. The project will investigate the economic interrelation between freight shipments by and diesel purchases from one large American manufacturing company - General Motors. These variables will be used in connection with other relevant explanatory variables in an econometric model. The coefficients of the model will be estimated by single equation and multiple equation methods including ordinary least squares and two stage least squares. The data were derived from public records with the cooperation of General Motors. The results will provide one type of information concerning the existence of reciprocity in economic activity. (Resek)

2463-72122 T Chemistry and Chemical Engineering. Molecular Orbital Calculations on Square Planar Compounds. This research consists of doing extended-Hückel-type molecular orbital calculations on the square planar complexes of platinum (II). The resulting molecular orbitals will be studied to attempt to determine the theoretical foundations of the trans effect, which is so important in the reactions of platinum (II) compounds. The mathematical methods to be used for this study are those which are standard to extended-Hückel-type molecular orbital calculations. These include such operations as Jacobi diagonalization and Gram-Schmidt orthogonalization. In the molecular orbital calculations these operations are used repeatedly. (S. Zumdahl)

2464-72123 T Economics. Money Supply Analysis. The research objective is to attempt to determine what factors are important to the Federal Open Market Committee of the Federal Reserve System in deciding upon the policy actions that are undertaken in conducting U. S. open market operations. Data for this study have been provided by the Federal Reserve Bank of St. Louis. The statistical methods used are primarily regression and correlation analysis. (J. E. Peirce)

2465-72126 T Electrical Engineering. Optimum Element Spacings for Maximum Directivity of an Arbitrary Antenna Array. The optimization of element spacings of any antenna array will be investigated. There is no restriction as far as the spacings are concerned. This problem will be investigated in two steps. (1) Theoretical approach: Derive all the necessary equations, simplify them, and, hopefully, combine them to a more compact and easy to manipulate form. (2) Numerical method: Computer programs will be written and used to find the optimization element spacings. The first program will use a "trial and error" method. The second program will use a gradient method - a fast optimization seeking technique which, it is hoped, will solve this problem in an easier and faster way. After the required solutions have been obtained from the numerical method, they will be analyzed to determine how much improvement in directivity can be achieved without the super gain effect by spacing the elements correctly. (Chun-Hing Leung)

2466-72127 State Water Survey. Hail Evaluation Techniques. This project is concerned with the development of methods for evaluating hail modification efforts in Illinois. Primary methods to be developed and studied include: (1) the use of radar (both planned-position indicator (PPI) and range-height indicator (RHI) displays) to measure the incidence of hail; (2) the use of hail insurance records to describe the areal extent and damage statistics on a daily and seasonal basis; (3) the use of long-term Weather Bureau records of hail incidences at points and over varying sized areas to measure the temporal frequency of hail; and (4) the development of hail-measuring instruments to be used in future field projects to measure hail intensity. Analysis of historical radar records, insurance data, and hail-days data will be performed to produce several probability expressions that can be employed as a measure of the natural variability of hail conditions. The results should also be meaningful in suggesting proper designs of hail modification programs. An intensive study of all hailstorms in east central Illinois during the April-September period of 1967 and 1968 will be pursued to furnish additional radar-hail data. The computer will be employed to construct three-dimensional statistics from the PPI radar portrayals. All radar data on hail days will be transferred to IBM cards. Radar echo characteristics for echoes above surface hail

reports are to be established (areal dimension, intensity, height) for the time of hail, before hail, and after the time of hail. It is likely that the computer also will be employed in the final stages of the probability analysis of the insurance and hail-days data. (Stanley Changnon)

2467-72128 T Economics. Simulation of Production Data. The purpose of this project is to analyze specification bias of parameter estimates in Cobb-Douglas production functions. Monte-Carlo simulation is used to generate all input variables. Coefficients of regressions and correlation matrix for input variables are obtained from empirical data. Various assumptions are added to give different aspects of specification errors. The computer is used to simulate all cases under study. (Herbert H. Tsang)

2468-73002 Bureau of Institutional Research. An Exploratory Study of the Relationships Among Graduate Education Variables. The purpose of the study is to investigate correlational relationships between several "input factors" of graduate education, such as number of instructional faculty, dollar support of research, square feet of laboratory space available, etc., and the number of student credit hours taught, degrees granted, etc., in selected departments on the Urbana Campus of the University of Illinois. Data to be used in this analysis will be secured from the Office of Admissions and Records, Central Office on the Use of Space, Bureau of Institutional Research, and the Graduate College. Relationships discovered in this study may serve as tools in the more efficient allocation of resources for graduate education. (John Terwilliger)

2469-73003 Psychology. Psychology Senior Honors Research. The nature of the research problem is varied since the request is for the honors thesis research of seniors in the Department of Psychology Honors Program. The research of Madeline Gonsky and David Schickedanz concerns the effects of drugs on learning and performance of retarded children. The experiments of Linda Rogers and Darlene Zientarski focus on the relation of the repression-sensitization personality dimension to physiological correlates and sensory deprivation. The studies of Harold Knoll and Stanley Rest deal with attitude change and personality variables. Arnold Slive's research

investigates different storage systems for short and long-term memory. Donald Thomas is studying whether teacher induced change in children's disruptive behavior is possible through behavior modification techniques. The mathematical methods to be used in most of these studies are forms of analysis of variance or correlation and are currently available in the SSUPAC library. (Kennedy Hill)

2470-73004 T Aeronautical and Astronautical Engineering. A Parametric Study of Staged Ejectors. A major advantage of staged ejectors, consisting of a primary (pumping) fluid, issuing from a supersonic nozzle enclosed in a constant area duct, mixing with a subsonic secondary stream, is the high compression ratios attainable. For a given area ratio (defined below), it is reasonable that the operating point occurs at the local sonic speed of the secondary flow. This condition is utilized in the optimization, i.e., least mass flow for maximum compression ratio, of ejector systems. However, the minimum entropy loss between the two fluids, hence the maximum compression ratio, occurs at a secondary Mach number less than one and at a minimum area ratio. From the above considerations and the large number of variables present in the ejector analysis, a parametric study of ejectors is desired. The parameters are: M_s - secondary Mach number; R - pressure ratio - total primary pressure/total secondary pressure; r - compression ratio - total exit pressure/total inlet pressure; Am/A* - area ratio - mixing duct area/ supersonic (primary) nozzle throat area; m - mass flow ratio - total mass flow/secondary mass flow. From these it is desired to obtain: (1) maximum r, imputing and varying M_s, R, and Am/A*; (2) r and r/R (to find locus of optimum points), varying M_s for: (a) Am/A* variable, m constant, (b) Am/A* constant, m variable, (c) Am/A* and m constant; (3) m as a function of R and M_s. The procedure involves varying the imput parameters through a range of pre-determined values. It is hoped that an insight into the operation of staged ejector systems can be secured from this study. (M. T. Delaney)

2471-73005 T Education. The Development of Moral Judgment in Average and Gifted Children. The computer will be used to analyze data gathered locally on 165 students ranging in age from nine to twelve. The students were administered a questionnaire based on the work done by Piaget. The general hypotheses are based on his theories. The computations will include chi square tests and correlations, which will be used to compare answers on the basis of I.Q., socio-economic class, and sex. (Geraldine Manahan)

2472-73006 T Political Science. Political Socialization of Colombian Students. The material being analyzed is part of a research project carried out in several Colombian primary and secondary schools during the past year. Several political, sociological, and psychological variables were used in order to analyze the influence of the different school environments on student attitudes toward political decision makers. Comparisons will be made between the attitudes of students of different grade levels within each school and between those of students of similar grade levels from the different schools. The research material was collected by means of questionnaires, interviews, and observations. The student responses will be analyzed in terms of their frequency distributions within the categories of approximately fifty variables. In addition, the correlations among many of these variables will be examined. (Jon Heggan)

2473-73010 Psychology. Perceptual Distance Under Varying Conditions of Noise. The data were supplied by observers who judged the distance of square, plane stimuli seen in a standard viewing alley. On each trial of an extended series of trials, a stimulus square of a specified size was located at a specified distance from the observer. He viewed the stimulus for 2 seconds and then classified its distance from himself, using 5 different classes ranging from "very near" to "very far." The stimulus squares varied in size as well as distance, the squares seen in the whole trial series consisting of all combinations of 5 distances and 5 sizes. All combinations of distance and size occurred equally often.

The analysis of the data concerns the extents to which the distance classifications of the observers were determined by the sizes of the squares as well as by their physical distances. The computations consist of three types. First, the response class tables are formed. In the case of each response class the table consists of a 5 x 5 table in which cells contain the frequencies with which each size-distance combination was assigned by the observer to that response class. Then the centroid and the sums-of-squares and cross-products matrix for each response class is computed. The second class of computations describes a single discriminant that best separates the response centroids as plotted in a size-distance plane. This is

the solution, first, to the equation

$$|W^{-1}B - \lambda I| = 0$$

in which W is the within-response-class sum-of-squares and cross-products matrix and B is the between-response-class sum-of-squares and cross-products matrix. After computing the inverse of W, the solution for λ is obtained by evaluating the determinant. The obtained value of λ is then used in solving for the normalized vector, X, in

$$(W^{-1}B - \lambda I)X = 0$$

which provides the direction cosines of the discriminant in the size-distance plane. The extent to which the response class centroids are separated on the discriminant is then computed.

The third type of computation applies a maximum-likelihood observer model to predict stimulus classification on the basis of projected stimulus locations on the discriminant or on any other directed line in the size-distance space. The quantities required for these predictions are the distances separating each stimulus from each response-class centroid, as projected on the directed line, and the response-class variances, as evaluated in the specified direction. The projected locations of the stimuli and the response-class centroids are obtained by premultiplying the 2 x 12 matrix of stimulus and centroid coordinates in the size-distance plane by the vector of direction cosines. The required response-class variances are obtained from

$$X'D_kX$$

in which D_k is the variance-covariance matrix of the k^{th} response-class and X is the vector of direction cosines.

Further computations of the same types, but somewhat greater complexity, are required for the stimulus cases involving more than size and distance variation. In some cases stimulus sets varying in hue or in the texture of the stimulus squares, as well as in size and distance, were used. The same methods applied to the case of the stimulus size-distance plane are applicable to the resulting stimulus three-space. (Harold Hake)

2474-73011 Library Science. Characteristics of Academic Librarians. This project is a national manpower study of academic librarians. Its major purposes are to provide current data on the characteristics of professional personnel in college and university libraries, and to examine how such factors as education, work experience, age, etc., affect employment status. The mathematical methods used will include frequency counting, significance testing (chi-square, t-tests, etc.), measures of association (Pearsonian R, Goodman and Krushkal's gamma and lambda, etc.), analysis of variance, and factor analysis. In addition a program prepared by the University's Survey Research Laboratory will be used in calculating sampling errors from clustered data. The study data were collected in a two-stage probability sample of academic librarians. The first stage involved a stratified, systematic, clustered sample of all academic libraries. The second stage involved a stratified, systematic selection of professional personnel employed in sample institutions. The computer results will be used to draw inferences regarding the nature of various strata of academic librarians and the differences between such strata. (Anita Schiller)

2475-73012 T Education. Occupational Education for Selected Animal Science Jobs. This is a study to determine the opportunities for employment and the kind and level of competencies required for optimum job performance by new and by experienced workers in meat inspector and laboratory animal caretaker jobs in a twenty-five county area of northern Illinois. Thirty respondents from each of the jobs with sub-groups of ten administrators, ten supervisors, and ten workers assigned a rating on a five point scale to each of 84 items of competency to indicate kind and level of competency needed by new and experienced workers. The arithmetic mean of the ratings assigned by the 30 respondents from each job will be used as measure of the level of competency needed on each item by workers on that job. The Pearson chi-square test will be used to determine if there is a significant difference in the level of competency ratings of administrators, supervisors, and workers within each job. The Pearson chi-square statistic will also be used to compare the competency ratings of all respondents from the meat inspector job with those of all respondents from the laboratory animal caretaker jobs to identify items of competency needed in common by workers on both jobs. The computer will be used to summarize and analyze the data. (Leon Mayer)

2476-73013 Education. Frequency Count of Student Choices of Poetry. The responses of seven hundred fifty-one junior high school students to two forty-item forced choice instruments will be summarized to determine: (1) the total group's choices on poetry; (2) the group's choices when it is divided into sub-groups based on intelligence, sex, maturity, and educational background. The data will be useful in comparing this group's choices with those made by other researchers. (John E. Erickson)

2477-73014 Animal Science. Availability of Amino Acids for the Chick. The availability of various necessary amino acids in natural feeds such as soybean meal is being ascertained by feeding a basal ration supplemented with appropriate amounts of one required amino acid. By using either a natural feed or a crystalline amino acid, with all other required amino acids provided in adequate amount, the growth response of the check can be measured and growth rate for the natural feed can be compared to that for the crystalline amino acid, giving the availability of that amino acid in the natural feed. The data will be analyzed by the method of least squares, taking account of voluntary feed consumption as an important variable contributing to the growth response. (H. M. Scott)

2478-73015 Civil Engineering. Fatigue of Welded Highway Structures. A study is being conducted to determine the effect of different weld geometry parameters on the fatigue life of welded structural members. The geometry parameters are the height, width, flank angle, and radius, which are measured from plaster casts of welded fatigue specimens. Other parameters being considered are the ultimate strength of and the stress applied to the material. The study is based upon a multiple regression analysis which gives the least squares "best" value of these coefficents for a particular sample of observations. The solution also gives a measure of the reliability of each of the coefficients so that inferences can be made regarding the parameters of the population from which the sample was taken. The program works in a step-wise procedure. It determines which variable provides the greatest decrease in variance when added to the regression, and which variable will cause the least variance increase when removed from the regression. If the variance contribution is insignificant, the variable is removed before another variable is added. If the variable reduction due to adding a variable is significant, this variable is added to the regression. Once a sufficiently accurate

relationship between the dependent and independent variables is determined, the program is terminated by calculating the predicted values of the dependent variable and the deviation between the actual and predicted values. The results of this investigation will be used to improve techniques of welding and to improve the specifications for welded highway structures. (W. H. Munse)

2479-73016 T Chemistry and Chemical Engineering. Saturation Recovery. Calculations will be made to determine the effect of chemical exchange on non-steady-state nuclear magnetic resonance spectra for various initial conditions. The lineshapes are determined by the solution to a matrix differential equation namely:

$$\frac{d\rho}{dt} = A\rho + \rho_o$$

where ρ is a column vector containing the spin density matrix elements for the particular system under consideration. A and ρ_o are respectively a matrix and a vector of constant coefficients. The results will be used to show how chemical exchange rates can be determined from non-steady-state spectra. (E. S. Gore)

2480-73017 Children's Research Center. Prediction of Delinquent Behavior. This study involves the Pearson multiple and canonical correlational analysis of predictor variables and criterion variables on samples of juvenile delinquents. An original sample of approximately 150 will be cross-validated by a sample of similar size. Subjects are from Federal penal institutions. The results have applications to the prediction of both institutional and post-institutional behavior of juvenile delinquents. (H. C. Quay)

2481-73018 Anthropology. Costa Rican Census Data. The research problem involved is the tabulation of census data obtained from the Costa Rican Bureau of Census and Statistics. These data will be incorporated in a report on a summer field research project sponsored by the Department of Anthropology of the University of Illinois. The computer will be required to make tabulations and print-outs in two and three variable tables. (Odin Toness)

2482-73019 Physical Education for Men and Graduate PE. Effects of a Physical Training Program on Highly Anxious Middle-Aged Men. The purpose of this study is to determine the effects of a rhythmical and progressive training program on highly anxious middle-aged men as measured by the revised Pittsburg Taylor Manifest Anxiety Scale. Three groups of subjects are involved in the study: Group A, a highly anxious group; Group B, a low or moderately anxious group; and Group C, a control group, composed of subjects of various levels of anxiety. Both Groups A and B will participate in a three day a week training program of six months duration. Data will be collected in part from the Sanborn Four Channel Recorder and the Cameron Heartometer. Various cardiovascular measures will be tested at rest, during, and at the completion of a physical and mental stressor. Computation of statistical data will be as follows: (1) Analysis of covariance between Groups A and C to determine any significant improvement in cardiovascular fitness; (2) Paired t-test to determine significant improvement within Group A; (3) Analysis of covariance between Groups A and B to determine difference in improvement due to anxiety levels. (Maurice J. Jette)

2483-73021 Civil Engineering. Plotting High Strength Steel Fatigue Test Data. Test parameters and results have been extracted from approximately eighty reports covering studies of the fatigue properties of high strength steel used for the construction of large naval structures. Variable test parameters included both test conditions and specimen configurations. The ultimate goal of this project is to develop meaningful design relationships based on the behavior information extracted from the reports. One of the primary methods of evaluating the significance of varying fatigue test parameters is to plot (on a log-log scale) the curve of maximum stress vs. number of cycles to failure of the test specimen. This is called the S - N curve. It is intended, in this problem, to select the test data points meeting many different combinations of test and specimen parameters, to compute by the least squares method the S - N curve best fitting the points selected, and to plot the points and curves on the CalComp Plotter. In this manner, the effects of the parameters can be evaluated by comparison of the curves, and the design relationships can be formulated. (W. N. Ekstrand)

2484-73022 Materials Research Laboratory. Crystal Structures of Transition Metal Compounds. The structures of several transition metal complexes are being investigated, particularly those of vanadium and copper. Alpha-hydroxycarboxylic acid chelates of vanadyl(IV) and varicus copper compounds are under intensive study at present using single crystal X-ray diffraction techniques. The computer is being used to analyze and process the data obtained by the X-ray diffraction work by the calculation of structure factors, determination of Fourier plots, fitting of data by least squares methods, and calculation of atomic positions and parameters. In addition the CalComp plotter will be used to obtain final drawings of the structures using the Oak Ridge Thermal Ellipsoid Plot (ORTEP) program. (R. L. Belford)

2485-73023 Department of Computer Science. ILLIAC IV Study of Partial Differential Equation Problems. A study of numerical methods for the solution of problems in partial differential equations is being conducted to determine their suitability for use on ILLIAC IV. Special emphasis is given to the development of codes for hydrodynamic and reactor calculations. The 7094 is used in modeling the parallel processor, testing prospective algorithms, and making timing estimates. (P. J. Wallack)

2486-73024 Physical Education for Men and Graduate PE. Proprioception and Time Estimation. The effect of varying proprioception variables in a simple motor response on lapsed time estimation is to be analyzed by a 4 x 2 x 6 3-way factorial design. The objective is to clarify the role of force and positicn feedback as a chronometric system in humans. At least 80 subjects in four groups will learn to estimate a two-second interval under four different feedback conditions for 30 trials. The proprioceptive feedback will be (1) minimised, or will consist of (2) force, (3) position, or (4) force and position feedback. Knowledge of results will be provided by the experimenter for the first phase of 30 trials and will then be withheld for the second phase. (M. J. Ellis)

2487-73025 T Sociology. Organizational Study of a Welfare Agency. The research is an organizational study of the orientations of caseworkers towards clients, and agency supervision and procedure as they relate to group integration and cohesion. The data were gathered in structured interviews with caseworkers and supervisors. The SSUPAC programs Distribution Analysis, Correlations, and Clique Analysis will be used in analyzing the data. (Frank Weed)

2488-73026 T Psychology. Percept. This study consists of two parts. The first is an empirical definition of the Negro and the "working-class" stereotype as they exist among university undergraduates. This will be accomplished by having subjects rate the "typical" white, Negro, professional, and working-class American on each of 107 descriptive adjectives according to the probability of possession of each of the 107 traits implied by the adjectives. Two independent samples will be used, and paired t-tests will be done between Negro and white, professional and working-class for each of the 107 adjectives, for each sample. The results will then be compared across samples, and those adjectives will be selected which show significant differences in both samples. The adjectives thus selected will then be intercorrelated and factor-analyzed to determine if any underlying dimensions exist within the stereotypes thus obtained.

The second part of the study involves the use of the obtained stereotypes in an investigation of two classes of variables on the process of person perception and stereotyping. Complex stimulus persons, systematically varied on the dimensions of race, occupational status, social background, and social behavior, will be presented to subjects to be rated on the adjectives selected to represent the Negro and working-class stereotypes. Subjects will also fill out an "attitude toward civil rights" scale which serves as a measure of prejudice, and a "response-set" measure intended to discriminate those who habitually mark extreme ends of rating scales. In addition, three methods of rating each complex stimulus person will be used: an adjective checklist, a semantic-differential, and a probability-judgment scale. Each method will have its own response-set measure.

The dependent variable used in the analyses will be the subject's mean "stereotype" score divided by the standard deviation of his score, for both the Negro and working-class stereotypes. This is intended to provide a measure of both extremity and polarity of judgments. If separate factors exist within these stereotypes, they will be analyzed separately; that is, means and standard deviations will be taken for each factor, and used as the dependent variable score. Each method will also be analyzed separately. Thus, a series of 2x2x2x3x3 analyses of variance will be performed: two levels each of race (Negro-white), social background (professional-working-class), occupational (professional-working-class), three of social behavior (assimilation, aggression, withdrawal), and three of prejudice (top, middle, and bottom 1/3 of attitude-scale distribution). Response-set measures will be

correlated with stereotype scores, for each method. A Campbell-Fiske multitrait-multimethod analysis will also be performed, consisting of intercorrelation matrices of all adjectives by all methods for each cell of the design. Cell intercorrelations may also be performed.

It is then possible to determine the following: (1) The influence of both information about a person and the subject's evaluation of that information on the way the stimulus person is perceived. (Prejudice is considered to be, in part, selective attention to certain characteristics of a stimulus person to the exclusion of others.) (2) The extent to which the method of gathering information influences the results obtained in studies of stereotyping and person perception. (3) The influence of response set on each of the methods under consideration. (J. Feldman)

2489-73027 T Geology. Foraminiferal Diversity on the Shelf of North Carolina. Species diversity factors are to be computed from faunal data which were obtained during a study of the foraminifera of the continental shelf of North Carolina. Eighty-five samples are to be analyzed, which contain an average of 400 specimens each. The number of species, for all samples, is about 145.

Species diversity of benthonic foraminifera is an indication of the variability of the environment in which they live. It is a factor of the relationship between the number of species found in a sample and the number of specimens present in each of the species. Species diversity is usually low in variable (or restrictive) environments and high under normal marine conditions. The diversity data, plotted on a map, will permit conclusions to be drawn with regard to the prevailing oceanographic conditions of the study area. (Detmar Schnitker)

2490-73028 Nuclear Engineering. Static and Dynamic Behaviour of Critical Assemblies with a Specified Fission Rate Density. The static and dynamic behaviour of a critical assembly is studied using the concept of a specified fission rate density. The analysis is carried out using a two-group diffusion theory model. A parametric study of fuel loading and flux as a function of assembly size and material composition will be made on the computer. For this study a three region reflected assembly will be used. A two region reflected

assembly will be used for a dynamic study of the effects of fission product poisoning. The non-linear differential equations for this calculation will be solved iteratively on the computer. (R. A. Axford)

2491-73029 T Chemistry and Chemical Engineering. Oscillations at a Fusion Front. The problem being considered is a moving boundary problem between a solid and its melt. A finite difference method will be used to solve the problem theoretically. This is the Murray-Landis method with certain modifications. The solution will then be compared with experimental results. Under certain conditions, oscillations of the boundary (interface) occur. Predictions of the conditions under which this occurs will be attempted. A mathematical model predicting the behavior of the oscillations will be attempted, solved, and the results compared with experiment. (W. L. Heitz)

2492-73030 Illinois State University, Normal, Department of Educational Administration. Congruence and Dissonance in the Ecology of Educational Administrators as a Basis for Predicting Leader Behavior. The study will evaluate a method of predicting the leader behavior of secondary school principals based on the degree of congruence between the needs of the individuals' personality and the press of the academic environment in which they work. The predictor variables were obtained by administering the High School Characteristics Index to ten randomly selected teachers in the sample high schools, to describe the press of the environment in their respective schools, and by administering the Activities Index to the subject principals to elicit measures of their perceived personality needs. The difference between scores on the parallel scales of the two instruments will be computed to provide the needs-press congruence scores to serve as the predictor variables. Scores from the Leader Behavior Description Questionnaire were used to establish the dichotomous criterion to be predicted--effective and ineffective leader behavior. Other predictions of ancillary criteria will be made also. The discriminant function technique will be the fundamental statistical technique used to ascertain the extent to which the predictor variables will discriminate between the various dichotomous criteria. (Gary Olson)

2493-73031 Chemistry and Chemical Engineering. Crystal Structures of Steroids. Crystal structure studies are being carried out on a number of steroids of unusual structure. The X-ray method is a powerful and unique tool to establish structures of organic molecules. The methods being used are mainly those involving heavy atom techniques. The computations involve structure factor calculations, formation of Fourier series, and refinement by least squares techniques. (I. C. Paul)

2494-73032 Chemistry and Chemical Engineering. X-ray Studies on Biologically Important Molecules. X-ray studies are being carried out on biologically important molecules. The X-ray method is a powerful and unique tool to establish structures of organic molecules. The methods being used are mainly those involving heavy atom techniques. The computations involve structure factor calculations, formation of Fourier series, and refinement by least squares techniques. (I. C. Paul)

2495-73033 Chemistry and Chemical Engineering. X-ray Crystal Structure Analysis. The methods of X-ray crystal structure analysis are being used to investigate the molecular structure of a series of related compounds. Studies are proposed on some molecules related to ferrocene, particularly derivatives where bridging groups give the geometry a certain degree of rigidity. Metal carbonyl complexes of aromatic hydrocarbons are also being studied, particularly complexes with molecules containing seven and eight-membered rings. The methods being used include the heavy atom method and the direct phasing approach. Programs being employed are principally calculation of structure factors, evaluation of Fourier series, and least squares refinements. (I. C. Paul)

2496-73034 Institute of Research on Exceptional Children. Symbolic Family Estates. This study is designed to investigate social class differences in kinship structure and the forms of family estates which are passed down from generation to generation. Two kinds of estates will be considered--symbolic and non-symbolic. The focus will be on the symbolic family estates. Symbolic family estates consist of such things as personal biography and access to economic and political institutions by kin. Data on relatives of about 200 families have been collected through interviews with the husbands and wives in these families. Data on about 4,000 relatives will

be included in the analysis. The computer will be used to perform factor analysis, multiple regression analysis, discriminate function analysis, and cross-tabulations and computation of percentages. This study is part of a larger project sponsored by the U. S. Office of Education to provide information about communities which will be beneficial to the development of preschool programs for the culturally disadvantaged. Accordingly, the results will be transmitted to developers of educational programs for the culturally disadvantaged. (Bernard Farber)

2497-73039 Institute for Research on Exceptional Children. Biological Sciences Curriculum Studies. This problem is an analysis of factors contributing to variation among classes being taught the same subject matter by teachers trained in the techniques of presenting the material. Statistics utilized will include determination of (D) score on the semantic differential and analysis of covariance. This problem is part of an overall study of classroom behavior. The main emphasis is on developing a system of classification of interaction patterns to determine differences in styles and conceptual levels among teachers. IQ's, achievement tests, and psychological tests of class members are analyzed in part of the study to determine relationships between classroom patterns and individual members' contributions. Data for the study have been gathered by tape recording actual classes, then transcribing the material in written scripts, as well as by administering to members of some of the classes a variety of standarized psychological and achievement tests. (James J. Gallagher)

2498-73040 T Biophysics. Factor Analysis of the Auditory Evoked Cortical Response. The data were obtained from the evoked cortical responses of human subjects exposed to loud sounds. The data will be normalized on the computer, and fifteen different measures of the evoked cortical response extracted. These will be combined with three more variables (estimated loudness, sound intensity, and frequency), and an 18-by-18 correlation matrix will be computed. This matrix will then be factor-analyzed using the principal factors and iterative methods, and a varimax rotation of the axes performed. The computer results will be used to determine the relations between subjective estimates of loudness and various components of the auditory evoked cortical response in humans. (Howard Rothman)

2499-73041 Education. Role Conflict of Rehabilitation Counselors. Ninety-eight counselors employed by the State Division of Vocational Rehabilitation were mailed a questionnaire which listed the 15 activities normally performed by counselors and were asked to give a rank order distribution of these activities. These activities were ranked four times as to: (1) how the counselor felt he was best qualified to perform; (2) how the counselor would perform if he were free to spend his time as he chose; (3) how the counselor felt the agency regarded and rewarded these various activities; (4) how the counselor actually spend his time on the job. A mean, standard deviation, and rank order distribution will be computed for each ranking. An analysis of variance will then be computed to determine if there were any significant differences within each ranking according to the following counselor variables: age, sex, experience, and training. An analysis of variance will also be computed to determine if there were any significant differences in the 15 activities among the four rankings. (Harold A. Moses)

2500-73042 T Mechanical Engineering. Steam Generator Performance. The computer program performs a steady state energy balance by iteration and integration for a once-through steam generator in an atomic power plant. Computer output is to be compared with data obtained at the plant. Liquid sodium passes through the steam generator heating feedwater to superheated steam sufficient for turbine generator operation. By varying the feedwater flow rate, liquid sodium flow rate and temperature, and feedwater/steam pressure, the program will produce information for predicting stable steam generator operation. (Rawls W. Walden)

2501-73043 T Civil Engineering. Dynamic Behavior of Cylinders. The problem under study is one of determining the behavior of a cylindrical tube-like structure which is surrounded by an elastic restraining medium when the structure is subjected to uniform radial forces over segments of varying sizes around its perimeter. The results that will be obtained, although for an idealized case, are expected to increase our understanding of the behavior of underground, vertically oriented silo-type structures when subjected to the pressures induced in the surrounding soil by passage of an air-blast wave over the ground surface above the structure. (B. M. Cowan)

2502-73044 Zoology. Population Dynamics. Two types of related programs involving the growth of animal populations will be carried out. First, using a series of laboratory measures as base data, the growth of zooplankton and associated algae upon which the animals feed will be simulated. This part of the project will commence as soon as the DYNAMO program now being prepared for the IBM 7094 is ready (probably within a month). Second, analyses of growth and size distribution curves obtained with a linked Coulter Counter and multichannel analyzer will be performed. The primary mathematical techniques employed in this latter phase are statistical, though some curve fitting will be done. (Charles E. King)

2503-73045 Psychology. Calculation of D-Prime. In order to obtain a measure of human perceptual sensitivity in a variety of experimental situations that is relatively free of subjective criterion shifts, a D-prime as described in the Theory of Signal Detectability may be calculated. This calculation was previously done on normal-normal graph paper by plotting the probability of a "yes" response given noise vs. the probability of a "yes" response given a signal, and fitting a line by eye. This procedure can be further quantified by using the SSUPAC correlation program to determine the best least-squares line fitting these data. The X intercepts for the Y on X and X on Y regression equations are averaged to obtain the most stable D-prime. (Charles Eriksen)

2504-73050 T Speech and Theatre. A Toulminian Analysis of Cognitive Consistency. Data were obtained from human subjects who rated a number of statements in terms of the degree to which they believed each to be true. The statistical tests involved are simply correlations between the ratings on one set of statements and the ratings on another set. In order to arrive at these scores, the following mathematical methods are used: simple summation, simple averaging, Bayes theorem (which involves multiplication and division of probabilities), and the formula for finding the joint probabilitites of events which are not mutually exclusive. The derived correlations will be used to test the hypothesis that the strength of belief in statements which are claims in terms of Toulmin's model of logic is a function of strength of belief in statments which, according to the same model, are data and warrants. (John Schunk)

2505-73051 Department of Computer Science. A Monte Carlo Study of the Average Number of Searches in a New Directory Structure. A method for storing tables and subsequent look-up has been developed which incorporates most of the advantages of the two previously used methods: (1) the contiguous-sequential table structure, which is particularly amenable to the binary-chop type of search; and (2) the sequential-pointer-linked structure which is readily modified as the table is altered. An important measure of goodness of any method of directory structure is the average number of search times to locate an item (for insertion or retrieval). In the case of this particular method, the number of search times depends highly on the ordering of the items to be entered, and in a non-analytical fashion, necessitating the generation of a substantial number of random cases. By Monte-Carlo-ing in this manner, a reasonable value for the average number of searches should be established. (David E. Gold)

2506-73052 Food Science. Parameter of a Function of Overlapping Gaussian Curves. The purpose of this study is to provide a program for the evaluation of the various quantities of interest in the following physical and chemical analytical techniques: electrophoresis, ultracentrifugal sedimentation, gas chromatography, column chromatography, x-ray diffraction, and absorption spectroscopy. All of the techniques yield plots or patterns which can be represented by a function which is the summation of a number of overlapping asymetric gaussian curves. Earlier efforts to use the ILLIAC I for this purpose resulted in a program which successfully resolved the pattern into their component curves provided they did not overlap seriously. It is proposed to attempt the development of a program for the IBM 7094 which will resolve overlapping components as well. (R. M. Whitney)

2507-73053 T Psychology. Repression-Sensitization 3. This study is part of a construct validity approach to study of the dimension of repression-sensitization. Alpha reliabilities and intercorrelations among several questionnaires will be computed, and represser-sensitizer differences in magnitude of correlations will be investigated, as part of an inquiry into the extent of individual differences in response consistency. The first step is to obtain scores for a large group of student subjects on Byrne's Repression-Sensitization scale, Eysenck's Extraversion-Introversion and

Neuroticism scales, and Pettigrew's Category Width scale. The alpha reliabilities and intercorrelations among questionnaires will be obtained for the whole group of subjects. Next, subjects will be divided into two groups on the basis of Repression-Sensitization scores. After equating the two groups for variance, they will be compared for size of alpha reliabilities on Eysenck's and Pettigrew's scales, in the expectation that repressers will show greater response consistency. Size of intercorrelations among the three questionnaires will then be compared for repressers and sensitizers, again in the expectation that repressers will show more consistency. Eysenck's two scales have been administered on two separate occasions. Test-retest correlations will be computed to provide a measure of stability over a one-week period. Possible represser-sensitizer differences in stability will be investigated by comparing size of the test-retest correlations for these two groups of subjects. Correlations between Byrne's Form A of the Repression-Sensitization scale and a revised Form B will be obtained, in order to investigate the possible influence of acquiescent response bias on Repression-Sensitization score. Size of the correlations will again be compared for repressers and sensitizers. If individual differences in response consistency are found to be fairly stable and general across various questionnaire measures, results will have implications for the interpretation of conflicting findings by different investigators performing correlational studies. (Barbara Blaylock)

2508-73054 Special Education. A Study of the Effects of Two Experimental Curriculum Units on the Social Perception and Pre-Vocational Readiness of Educable Mentally Retarded Adolescents. The objectives of the present study are to (1) study two curriculum approaches to determine their effectiveness in training junior high school adolescent retardates in social perception and inference and in occupational readiness, (2) determine differences in the effectiveness between the two curriculum approaches, (3) determine whether weekly unit tests in the social perception curriculum unit will be predictive of performance on validity criterion measures, and (4) determine teacher and pupil evaluations of the social perception curriculum unit. The data were obtained by pre- and post-measures using the Test of Social Inference, the Vineland Social Maturity Scale, the Bown Self-Report Inventory, the Fudell Test of Occupational Readiness, and a Behavior Rating Scale.

Evaluation data were obtained by forms presented to the teachers and pupils to complete after daily units. An experimental and a placebo class were constituted randomly in each of three different schools in metropolitan Nashville - Davidson County, Tennessee. The experimental and placebo curriculum units were administered over a ten week period. Subjects were of junior high school age and had a range of ages from 12-0 to 16-0. The first two objectives will be studied by an analysis of variance procedure with repeated measures, using a program from Balanova Five Program Supplement. This analysis of variance will yield intersubject and intrasubject comparisons for each measurement device. The teacher and pupil evaluations will be analyzed with descriptive statistics. The weekly unit test on the experimental curriculum will be correlated with each of the post-test measures on the five primary criterion instruments. (Gary M. Clark)

2509-73055 Education. The Blind Learning Aptitude Test. The purpose of this study is to develop a learning aptitude test for blind children (BLAT) aged 6 to 16 inclusive. Test and background data have been collected, and will be punched for analysis, on some 1200 subjects in residential and day schools for the blind in 11 states. The data, coded where appropriate, to be punched and machine analyzed are the following kinds: (1) Background: School identification, visual impairment condition, sex, age, socio-economic status. (2) Psychometric tests: Hayes-Binet results; Wechsler Intelligence Survey for Children (WISC) results; BLAT results, including total scores and item performances. (3) Educational achievement: sub-test scores. Minimal machine runs on these data will include the following: (1) Printout of tables of population descriptions, counts of specified variables (socio-economic status, race, age, etc.), and pass-fail frequencies by individual items. (2) Computation runs, including: (2.1) Ascertainment of selective means and standard deviations; (2.2) Conversion of raw scores to derived scores; (2.3) Reliability computations (Test-retest and Kuder-Richardson); (2.4) Inter-variable relationships (Binet-BLAT, WISC-BLAT, etc.); and (2.5) Possible factor analytic explorations. (T. E. Newland)

2510-73058 T Education. Paired-Associate Learning by Children with Downs Syndrome. Paired-associates were learned by 24 retarded children diagnosed as having Down's Syndrome, under four stimulus-response modalities (visual-motor, visual-vocal, auditory-motor, and auditory-vocal). Each subject learned four lists to a criterion of two consecutive correct anticipations of each pair, or ten trials, whichever came first. Error scores, by modality, will be analyzed to find the means and standard deviations. A two-factor (subjects by modality) analysis of variance will be performed. The results will be used to show which modality is associated with low error scores. Educational programming for these children may then be tailored so that new information is presented in the modality in which the children learned fastest. (Mrs. Scheffelin)

2511-73059 Materials Research Laboratory. X-ray Intensity Correction. When an electron beam strikes matter x-rays characteristic of the matter are produced. The wavelengths of the x-rays tell what elements are present, and the intensity of the wavelength tells approximately how much of a given element is present. It is known that x-ray intensities at a given wavelength from mixtures of materials do not accurately represent the concentration of a particular constituent and therefore require intensity corrections. The purpose of this program is to correct "raw" x-ray intensity data and render it useful for quantitative elemental analysis. (Fred Luehrs)

2512-73060 T Agricultural Engineering. Similitude of Model Tillage Tools. This is a study in dimensional analysis of model tools in which the tools are run through artificial soil at various soil conditions and speed. Using various soil properties and tool properties, dimensionless products can be determined. If the soil is properly scaled, the results measured on a model tool can be used to predict the forces on a prototype tool. From the data obtained, various curves will be plotted in which a statistical approach will be needed. The computer will be used to do a simple correlation and multiple regression analysis of the data. The program will essentially use a least squares analysis along with other pertinent statistical information such as partial regression coefficients, regression sum of squares, residual sum of squares, and multiple correlation coefficients which will be used in the analysis of the data. (Larry W. Sprinkle)

2513-73061 Psychology. Responses to Social Pressures. Human subjects responded to scales on which they indicated their attitudes on twenty issues, and also indicated the confidence with which they held their attitudes, the probability that their views could be proven wrong, etc. Two months later, subjects received information indicating that majority opinion differed substantially from their own views on half of the issues. They then responded to the attitude scales for a second time. (Control subjects received no bogus information before responding for a second time.) Experimental and control groups will be compared with respect to amount of pro-majority change from time 1 to time 2, and the data from experimental subjects will be analyzed to determine the degree to which each of several variables mediated these subjects' responses to the manipulated variable (majority opinion). Partial correlation will be computed to reveal the mediating effects of each of six variables, and multiple correlation will be employed to reveal the combined effects of all six variables. (Ivan D. Steiner)

2514-73062 Chemistry and Chemical Engineering. Spin Echo Studies of Chemical Exchange. Nuclear magnetic resonance spin echo experiments will be performed on molecular systems undergoing rapid chemical exchange. Briefly, the experiment consists of determining the apparent decay constant $1/T_2$, in sec^{-1}, for the amplitudes of successive signal echoes in a Carr-Purcell train as a function of the radiofrequency pulse repetition rate $1/t_{cp}$, where t_{cp} is the time between echoes. Theoretical considerations indicate that this decay should be exponential, or very nearly exponential in all cases, and should be dependent upon: T_2°, the transverse relaxation time in the absence of exchange; $\delta\omega$, the chemical shift between the exchanging sites; τ, the lifetime between exchanges; and P_a and P_b, the relative populations of the two sites. These variables are related by the following expression:

(1) $$1/T_2 = 1/T_2^{\circ} + 1/2\tau - 1/t_{cp} \sinh^{-1} F$$

where $$F = (1/\tau\sigma)\sinh(t_{cp}\sigma/2) \text{ and } \sigma = [(1/\tau)^2 - 4P_aP_b(\delta\omega)^2]^{1/2}$$

All the parameters are known except T_2°, $1/\tau$, and $\delta\omega$. To facilitate the determination of these unknowns by a least squares method, equation (1) can be converted to:

$$(2)\quad 1/T_2 + \Delta(1/T_2) = 1/T_2^{\circ} + \tau^{-1}/2 - (1/t_{cp})\ \sinh^{-1} F + M\Delta\tau^{-1} + N\Delta(\delta\omega)$$

where $$M = \partial(1/T_2)/\partial\tau^{-1}\ ,\ N = \partial(1/T_2)/\partial(\delta\omega)$$

Values of τ^{-1} and $\delta\omega$ are initially assumed and equation (3) is solved for $1/T_2^{\circ}$, $\Delta\tau^{-1}$ and $\Delta(\delta\omega)$ which will minimize the sum of the weighted square deviations Σd^2.

$$(3)\quad d = (1/T_2) - (1/T_2^{\circ}) - M\Delta\tau^{-1} - N\Delta(\delta\omega) - (\tau^{-1}/2) + (1/t_{cp})\ \sinh^{-1} F$$

These values of $\Delta\tau^{-1}$ and $\Delta(\delta\omega)$ are added to the initial values of τ^{-1} and $\delta\omega$ and another least squares calculation performed. This process is continued until the values of $\Delta\tau^{-1}$ and $\Delta(\delta\omega)$ are suitably small. These computed values, determined for several temperatures, will be used to calculate the kinetic and thermodynamic dependence of the exchange process. (Don T. Dix)

2515-73063 Psychology. Evaluating Cognitive and Affective Outcomes of Teaching Psychology. This investigation is in two parts. Part I seeks to discover relationships between students' perceptions of their instructors' classroom behavior and how these students perceive their own orientation toward college life. Classroom behavior variables for instructors are: skill, structure, group rapport, feedback, miscellaneous positive behavior, and miscellaneous negative behavior. "Orientation" variables are: vocational, academic, nonconformist, and collegiate. Data were obtained by means of questionnaires administered to 1500 students in Psychology 100. The main analysis will be correlational. In addition, means and variances will be computed according to various biographical characteristics of students, and tests of significance between means performed. Tests will also be carried out to see what differences in college orientation exist in relationship to these biographical factors.

Part II of this investigation deals with the relationship between dogmatism and the reduction of misconceptions about psychology. It is hypothesized that dogmatism will be negatively correlated with the reduction of misconceptions, but not significantly correlated with achievement of conventional psychological information. (This study is a follow-up of one previously carried out by the present investigator.) Data were collected in introductory pyschology classes from 100 students by means of Rokeach's dogmatism scale and achievement tests constructed by the investigator. Correlational analysis (zero, first, and second order linear) will be carried out to test the primary hypothesis. (Frank Costin)

2516-73064 Agricultural Economics. Linear Programming for Individual Farms. The problem involves the development of a system of linear programming for individual farms. An existing L.P. routine (LP/90 or LPG1) will be used initially, but future viability of the system will depend on the availability of a larger and more efficient routine. Various input/output routines will be written to enable the storage of data on tape, and to permit the fitting of the relevant L.P. matrices by the machine. Output will be via a report-generator routine, which will produce reports in a form intelligible to the farmers involved in the program. (Scott)

2517-73065 T Special Education. Cognitive Achievement Through Independent Study in Summer Programs in Continuing Education. This study is intended to examine in-service training programs which combine independent study in content and group participation in the dynamics of interaction as operational procedure in changing teacher attitudes. Regional institutes dealing with practical problems related to the teacher's actual experience and a campus course on the education of gifted children may provide different environments for attitude change. The problem is to ascertain the degree of cognitive achievement gained by public school teachers and administrators participating in public school workshops through independent study, from a basic core of knowledge presently available in research findings concerning gifted children. During the summer of 1966 regional and university institutes were sponsored by the Office of the Superintendent of Public Instruction, Department of Program Development for Gifted Children, to provide training for public school personnel in the area of the gifted. Eight regional institutes were sponsored by public school districts or combinations of school districts to serve a

particular area of the state of Illinois. Each institute offered a program dealing with interests unique to that institute but with a common base of education for teaching gifted students. A diagnostic test of cognitive achievement in content on gifted was developed. Approximately 340 teachers and administrators were given the diagnostic test of content on gifted plus a test of mental ability and attitude surveys at the beginning of the Summer Institutes on Gifted, and the test of content on gifted and the attitude surveys were administered again at the end of the summer sessions. Data were collected concerning processes of study and subject emphasis for each workshop group. Statistical procedures are to be used to analyze the data and determine differences in achievement and attitudes among ten groups (eight regional institutes, a university institute, and a university course). Adjustment for differences of mental ability and for differences on pre-test scores will be made by analysis of covariance. If a significant difference is found, multiple comparisons will be made to find which groups vary. (Mary L. Kooyumjian)

2518-73066 Agricultural Engineering. Analysis of Farm Machinery Repair Costs. The primary objective of this project will be to determine the formulas for expressing repair cost rates for various types of farm machinery. Data will be taken from 800 farmer surveys in Illinois and 750 in Indiana. Standard regression techniques will be used in analyzing these data. (W. Bowers)

2519-73069 T Sociology. Social Status and Political Behavior. The primary focus of this study is upon the relationship between objective measures of social status (e.g., income or occupation), subjective measures of social status (e.g., respondents' attitudes), and political behavior (e.g., voting, partisanship, etc.). The data were gathered from certain portions of the Survey Research Center's (Michigan) 1960 Voting Study which were available on cards at the University of Illinois' Survey Research Laboratory. The computer will be used for recoding some of the data, for running frequency counts, for computing correlations, and for factor analysis. (James Grimm)

2520-73070 T Nuclear Engineering. Theory of Neutron Thermalization in a Multiregion Slab Cell, With Considerations of Chemical Binding. The energy dependence of neutron flux will be expanded in terms of $(\text{energy})^{1/2}$ in epithermal region and in terms of a suitable set of orthogonal functions in thermal region. Gas model with effective slowing down power and simple-harmonic-oscillator model will be used respectively for epithermal and thermal regions. To solve the transport equation the average slowing-down power is to be calculated numerically. The construction of the orthogonal functions and the expansion of neutron flux in terms of them will also be carried out numerically. (Yiu-Sing Liu)

2521-73071 T Chemistry and Chemical Engineering. Structure of Phosphonitrilic Fluoride Derivatives. The section of the problem which involves computer techniques is the structural determination. The work is in two areas, X-ray crystallography and nuclear magnetic resonance. The X-ray diffraction photographs were taken on an equi-inclination weissenberg camera and the intensities were visually estimated. Calculations to be performed include structure factors, Patterson functions, Fourier synthesis, etc. The phosphorus-31 and fluorine-19 nuclear magnetic resonance spectra were obtained on a Varian DP 60 and Varian 56/60A spectrophotometer, respectively. The program will calculate the allowed transitions and compare them to the observed spectral parameters in order to obtain accurate chemical shifts and coupling constants. These quantities may be related to the molecular structure in question. (C. W. Allen)

2522-73072 Mechanical Engineering. Non Linear Control System. This is a problem in the analysis of non-linear control systems. The control elements involve hydraulic components and backlash in gearing. The program is concerned with the investigation of analytic solutions and with numerical procedures to obtain system performance. The objective is to develop a program which will accept various linear transfer functions of a control loop plus a description of non-linearities and predict the existence of limit cycles. The data will be obtained from analog models of the system. The method of state variables will be used as the means of analysis. (G. V. Lombardi)

2523-73073 T Home Economics. Differing Instructions on the Film Test for Understanding Behavior. The Film Test for Understanding Behavior, a test designed to rate the ability of an adult to understand the needs of children, was administered to 146 students enrolled in Child Development classes, using differing sets of instructions. From this group 94 subjects were included in the study. They were all white, female, single, undergraduate, Home Economics majors who had never taken the test before. Two differing sets of instructions were used to learn their effect on test scores (total scores, subscale scores, and episode scores), using the Mann-Whitney U test. Test scores will also be correlated with the amount of previous coursework in associated areas using the Spearman Rank correlation. (Sue Owen)

2524-73074 T Materials Research Laboratory. Critical Indices. Exact high temperature expansions of the spin-spin correlation functions of certain magnetic models will be derived and analyzed to determine the effect of exchange anisotropy on the critical indices. The method of Padé Approximants will be used extensively, requiring the finding of roots of polynomials, and frequent matrix inversion. (David Jasnow)

2525-73075 T Mining, Metallurgy, and Petroleum Engineering. Stress Analysis for Viscoelastic Roof-slabs and Pillars. The object of this investigation is to obtain a more accurate and realistic means of determining the state of stress in bedded roof rocks and pillars using as a rheological model a viscoelastic slab resting on viscoelastic pillars. In particular, the Maxwell, Kelvin, three-element elastic, and Burgers models are chosen to simulate various types of roof and pillar material. The problem will be solved by the approximate method of difference equations, and a FORTRAN program will be written to solve for deflections, moments, and shears. (P. H. Lu)

10.2 Instructional Problem Specifications

During the first quarter of 1967, 15 instructional problem specifications were submitted to the Department for computation. The following brief descriptions of these problems have been prepared for inclusion in this report by those submitting them.

I537-71028 Ceramic Engineering 311. The Indexing of X-ray Powder Diffraction Patterns. It is anticipated that two kinds of problems will be run on the machine: (1) The computer will perform a Nelson-Riley extrapolation of the X-ray diffraction data for a cubic compound. A CalComp program will also be used to plot out the extrapolation for the determination of the precision lattic constant. (2) The computer will be used for indexing X-ray diffraction patterns of unknown compounds by the members of the class. SHARE program WD SORT, Distribution No. 1249, will be necessary as part of the program for solving this problem. The indexing program will determine if the crystal is cubic, hexagonal, tetragonal, or orthorhombic, and will also produce the lattice parameters of the crystal. (V. Tennery)

I539-71033 Accountancy 325. CAPERTSIM. This program consists of a FORTRAN II main program and four subroutines. It provides the class with an opportunity to simulate the experience of several scheduling problems. The program permits each student team to attempt alternative trials before making a final decision committing the team's effort. The program is written as a subprogram without a return, so that it can be made available on the system. (Mike Uretsky)

I565-72011 Physics 341. Oil Drop. A computer program is available to take oil drop data and print out results for the charge on the drop for each event. (A. O. Hanson)

I566-72012 Agricultural Economics 325. Linear Programming a Case Farm. The problem will be to program a case farm, using the SSUPAC or LPG1 linear programming routine. (J. T. Scott)

I587-72039 Electrical Engineering 272. Schematic Drawing. This is a continuation of a project to write an efficient 7094 program to produce schematic drawings on the CalComp plotter. The program in its present form has been compiled but may still contain errors. The first phase of the project this semester will involve debugging this program. The second phase of the project will consist of rewriting the various reading and error-checking routines so that the means of inputting data will be simpler and the program could be used by a person with limited programming experience. (A. W. Dipert)

I612-72078 Aeronautical and Astronautical Engineering 261. Aerodynamic Calculation. This problem will involve calculation of theoretical predictions and data reduction of experimental results as associated with the aerodynamic laboratory course. (R. H. Liebeck)

I641-72109 Ceramic Engineering 311. The Indexing of X-ray Powder Diffraction Patterns. It is anticipated that two kinds of problems will be run on the machine: (1) The use of a computer for performing a Nelson-Riley extrapolation of the X-ray diffraction data will be accomplished for a cubic compound. A CalComp program will also be used to plot out the extrapolation for the determination of the precision lattice parameters. (2) The computer will be used for indexing X-ray diffraction patterns of unknown compounds by the members of the class. The indexing program will determine if the crystal is cubic, hexagonal, tetragonal, or orthorhombic, and will also produce the lattice parameters of the crystal. (V. Tennery)

I642-72110 Physics 481. Problems in Quantum Mechanics. This course is the second semester of graduate Quantum Mechanics. It will cover atomic and (diatomic) molecular physics and related topics. Numerical calculation of simple one-dimensional Schrödinger wave functions, phase shifts, overlap integrals, matrix diagonalization, etc., will occur, and those students who are able are encouraged to use the computer. (D. G. Ravenhall)

I647-72131 Recreation 493. Recreation 493 Special Projects. The course provides basic instruction in the use of multivariate statistical techniques and computer analyses of data involving multiple measurements. Student projects will involve the analysis of data within and between several survey neighborhoods from Illinois cities. Multiple regression, discriminant analysis, and factor analysis will be the primary techniques used. One project, for example, will be the use of discriminant analysis to identify the combination of variables which maximally differentiates between the recreation interests of different neighborhoods. Most of the computer analyses will make use of the SSUPAC programs. (Doyle Bishop)

I648-72132 Nuclear Engineering 495. Inelastic Scattering of Neutrons in Iron. This is a continuation of a problem which originally started as a class project in NE 456, Reactor Physics II. The results and code will be used as a teaching aid in NE 455-6 in future years. The problem involves an idealized situation which is mainly of interest in illustrating the concept of inelastic neutron slowing. (G. H. Miley)

I656-73036 German 461. Literature Comparisons of 1790. Various lists, comparisons, and cross references are to be compiled from a source of approximately 4,000 entries. The information concerns all materials published in Germany in the year 1790. Besides the author and title, the data also includes publisher, place of publication, year of publication (not always 1790 because of continuations which are also included), price, format, etc. There is also much information which is not primary, that is, it must be coded not from the information on the entry, but from an examination of it. Such secondary data includes the language in which the book is written (many Latin, French, English, etc.), whether or not the book is a translation, its general category according to a predetermined classification system, etc. The information to be derived from these data includes a comparison of book price to general subject classification, a ratio and listing of original publications to translations, a ratio and listing of first editions of 1790 to later editions published in 1790, etc. This is in addition to the various listings according to price, city of publication, publisher, etc. (Mitchell)

I659-73046 Agricultural Economics 442. Parameter Estimation in Linear Statistical Models. The students' class problems will be concerned with estimating the parameters of economic relations through use of regression, stepwise regression, two stage least squares, three stage least squares, quadratic programming, and linear programming routines. The estimated relations will pertain to real or hypothetical demand, supply equations, and production functions. (George G. Judge)

I663-73056 Nuclear Engineering 454. Neutron Heating of a Plasma. The problem is to find out how many deuterons and tritons get heated up by collisions with neutrons, and how many nuclear reactions result from the fast ions then slowing down through the plasma. Calculations to be made include: hot ion source, nuclear reaction rates, rate of neutron energy deposition in plasma, rate of power generated by reactions, number of neutrons emitted by reactions, dependence of fusion probability upon electron temperature, and ratio of energy generated to energy deposited. Data to be used will be taken from the literature. Mathematical procedures to be used include curve fitting, interpolation, and triple integration using Simpson's three point rule. (Goldstein)

I665-73067 Political Science 497. Research Design and Techniques. Students in Political Science 497 do a project dealing with empirical data stored with the Survey Research Laboratory's Data Repository. Most of the data deal with individual interviews conducted during the past four Presidential campaigns. The students analyze the the data for their substantive content and as an exercise in methodology. The objective of the project is to familiarize the student with the way in which conclusions are drawn from data and to acquaint him with SSUPAC and programming languages. (A. H. Miller)

I666-73068 Economics 471. Regression Analysis. Each student is required to construct an economic model based on certain assumptions concerning the relations in the economy which generated the observed behavior; to estimate the parameters of the system; and to prepare all data decks and parameter cards and interpret the results. The models are multi-equation ones, no two of which are alike, and estimates are to be made by one- and two-stage least squares and limited information maximum likelihood methods of estimation. (Neiswanger)

10.3 Blanket Class Problem Specifications

During the first quarter of 1967, 117 problem specifications were submitted to cover all assigned problems in the following courses.

J535-71008 Chemistry and Chemical Engineering 348.

J536-71009 Chemistry and Chemical Engineering 398.

J538-71029 Psychology 307.

J540-71034 Nuclear Engineering 490.

J541-71035 Aeronautical and Astronautical Engineering 241.

J542-71036 Department of Computer Science 387.

J543-71040 Civil Engineering 474.

J544-71051 Mechanical Engineering 214.

J545-71052 Mechanical Engineering 263.

J546-71053 Mechanical Engineering 264.

J547-71054 Agronomy 441.

J548-71055 Agricultural Engineering 112.

J549-71056 Agricultural Engineering 336.

J550-71057 Electrical Engineering 323

J551-71058 Department of Computer Science 295.

J552-71059 Physics 471.

J553-71060 Mechanical Engineering 423.

J554-71061 Mechanical Engineering 260.

J555-71062 Vocational and Technical Education 456.

J556-72001 Mathematics 195.

J557-72002 Mathematics 149.

J558-72003 Department of Computer Science 400.

J559-72004 Department of Computer Science 996.

J560-72005 Civil Engineering 497.

J561-72006 Civil Engineering 497.

J562-72007 Agricultural Engineering 436.

J563-72008 Engineering Honors 297.

J564-72009 Sociology 495.

J567-72013 Educational Psychology 497.

J568-72014 Civil Engineering 497.

J569-72015 Mechanical Engineering 995.

J570-72016 Graduate School of Business Administration 544.

J571-72017 Mechanical Engineering 341.

J572-72018 Geography 495.

J573-72019 Mechanical Engineering 256.

J574-72020 Theoretical and Applied Mechanics 294.

J575-72021 Physics 303.

J576-72027 Department of Computer Science 458.

J577-72028 Aeronautical and Astronautical Engineering 429.

J578-72029 Aeronautical and Astronautical Engineering 427.

J579-72030 Chemistry and Chemical Engineering 349.

J580-72031 Agricultural Engineering 156.

J581-72032 Theoretical and Applied Mechanics 314.

J582-72034 Aeronautical and Astronautical Engineering 391.

J583-72035 Aeronautical and Astronautical Engineering 216.

J584-72036 Physics 341.

J585-72037 Geology 493.

J586-72038 Electrical Engineering 330.

J588-72042 Mechanical Engineering 221.

J589-72043 Mechanical Engineering 442.

J590-72044 Economics 272.

J591-72045 Civil Engineering 262.

J592-72046 Civil Engineering 391.

J593-72052 Electrical Engineering 250.

J594-72053 Entomology 317.

J595-72054 General Engineering 221.

J596-72055 Mathematics 395.

J597-72056 Mathematics 387.

J598-72057 Theoretical and Applied Mechanics 311.

J599-72058 Mechanical Engineering 405.

J600-72061 Civil Engineering 497.

J601-72062 Civil Engineering 461.

J602-72063 Electrical Engineering 324.

J603-72064 Theoretical and Applied Mechanics 432.

J604-72066 Electrical Engineering 386.

J605-72067 Psychology 390.

J606-72068 General Engineering 231.

J607-72069 Mechanical Engineering 186.

J608-72071 Civil Engineering 497.

J609-72072 Civil Engineering 368.

J610-72073 Electrical Engineering 389.

J611-72075 Aeronautical and Astronautical Engineering 262.

J613-72079 General Engineering 242.

J614-72080 Graduate School of Business Administration 574.

J615-72082 Graduate School of Business Administration 533.

J616-72083 Graduate School of Business Administration 553.

J617-72084 Chemistry and Chemical Engineering 469.

J618-72085 Mechanical Engineering 410.

J619-72086 Theoretical and Applied Mechanics 334.

J620-72087 Theoretical and Applied Mechanics 221.

J621-72088 Industrial Engineering 386.

J622-72089 Civil Engineering 316.

J623-72091 Theoretical and Applied Mechanics 315.

J624-72092 Mechanical Engineering 302.

J625-72093 Department of Computer Science 999.

J626-72094 Chemistry and Chemical Engineering 490.

J627-72095 Theoretical and Applied Mechanics 412.

J628-72096 Psychology 493.

J629-72097 Chicago Circle Physics 371.

J630-72098 Economics 471.

J631-72099 Physics 371.

J632-72100 Electrical Engineering 297.

J633-72101 Aeronautical and Astronautical Engineering 264.

J634-72102 Mechanical Engineering 332.

J635-72103 Electrical Engineering 332.

J636-72104 Chemistry and Chemical Engineering 381.

J637-72105 Mechanical Engineering 271.

J638-72106 Mechanical Engineering 224.

J639-72107 Economics 371.

J640-72108 Industrial Engineering 286.

J643-72124 Electrical Engineering 251.

J644-72125 Civil Engineering 361.

J645-72129 Theoretical and Applied Mechanics 493.

J646-72130 Chemistry and Chemical Engineering 422.

J649-72133 Electrical Engineering 322.

J650-73001 Civil Engineering 478.

J651-73007 Theoretical and Applied Mechanics 321.

J652-73008 Chemistry and Chemical Engineering 343.

J653-73009 Chemistry and Chemical Engineering 345.

J654-73020 Aeronautical and Astronautical Engineering 250.

J655-73035 Theoretical and Applied Mechanics 294.

J657-73037 General Engineering 231.

J658-73038 Physics 490.

J660-73047 Industrial Engineering 282.

J661-73048 Anthropology 450.

J662-73049 Mechanical Engineering 341.

J664-73057 Nuclear Engineering 495.

11. GENERAL LABORATORY INFORMATION

11.1 Personnel

The number of people associated with the Laboratory in various capacities is given in the following table:

	Full-time	Part-time	Full-time Equivalent
Faculty	15.0	2.0	16.0
Visiting Faculty	4.0		4.0
Research Associates	2.0		2.0
Graduate Research Assistants	4.0	82.0	43.4
Professional Personnel	17.0	1.25	18.25
Administrative and Clerical	20.0	2.0	21.0
Nonacademic Personnel (Monthly)	67.0	2.0	68.0
Nonacademic Personnel (Hourly)	3.0	117.0	42.0
TOTAL	132.0	206.25	204.65

The Computer Advisory Committee consists of Professor J. R. Pasta, Head of the Department; Professor J. N. Snyder, Associate Head of the Department; Professors L. D. Fosdick, H. G. Friedman, C. W. Gear, D. B. Gillies, D. J. Kuck, B. H. McCormick, S. Muroga, T. A. Murrell, J. Nievergelt, W. J. Poppelbaum, S. R. Ray, J. E. Robertson, and D. L. Slotnick.

11.2 Bibliography

During the first quarter the following publications were issued by the Laboratory.

File Numbers

(1) Amendola, R. C., "Functional Components of the ILLIAC III Remote Consoles," File No. 728, March 20, 1967.

(2) Carter, C. E., "Some Information from Bell Telephone," File No. 722, February 9, 1967.

(3) Divilbiss, J. L., "Iterative Array Wiring," File No. 731, March 28, 1967.

(4) Kato, Masao, "Hardware Design Problems for the Preliminary Specification of ILLIAC IV. III. Illiac IV Speed and Control Structure," File No. 727, March 10, 1967.

(5) Lewis, George, "A Simple Push Button Pulse Generator," File No. 723, February 1, 1967.

(6) Otis, A. B., Jr., "The Analog-Digital Programming System," File No. 726, February 23, 1967.

(7) Richardson, Fontaine K., "Graphical Computer Programming - Two Dimensional Computer Programming Languages," File No. 725-1, January 12, 1967.

(8) Richardson, Fontaine K., "Graphical Computer Programming - CAPS: Computer Aided Programming System," File No. 725-2, January 12, 1967.

Report Numbers

(1) Gear, C. W., "Numerical Integration of Stiff Ordinary Differential Equations," Report No. 221, January 20, 1967.

(2) Knowles, Michael; Okawa, Benn; Muroaka, Yoichi; and Wilhelmson, Robert, "Matrix Operations on ILLIAC IV," Report No. 222, March 1, 1967.

Specification Numbers

(1) Amendola, R. C., "Microfiche Readers: Bid Specifications," File No. 550-92, March 15, 1967.

(2) Amendola, R. C., "Film Scanner Mirrors - Optical Specification," File No. 550-93, March 23, 1967.

(3) Faiman, M., "Specifications for a Demountable Pockels Effect Modulation System," File No. 550-91, March 13, 1967.

(4) Kubitz, W. J., "Specification for Video Memory," File No. 550-89, January 4, 1967.

Theses

(1) Baugh, Charles R., "A Linear Programming Code to Determine Whether a Boolean Function is a Threshold Function," (M.S.), Report No. 218, January 6, 1967.

(2) Esch, John William, "System Design for Artrix Graphical Processor," (M.S.), Report No. 219, January 6, 1967.

(3) Oberbeck, Peter Ernst Rudolf, "Hybrid Circuit Design of the Artrix Graphical Processor," (M.S.), Report No. 220, January 7, 1967.

11.3 Numerical Analysis

"Numerical Quadrature I," by Professor L. D. Fosdick, Department of Computer Science, University of Illinois, Urbana, Illinois, February 28, 1967.

"Numerical Quadrature II," by Professor L. D. Fosdick, Department of Computer Science, University of Illinois, Urbana, Illinois, March 7, 1967.

"Illiac IV Programming of Several Problems in Partial Differential Equations," by Mr. P. J. Wallack, Department of Computer Science, University of Illinois, Urbana, Illinois, March 14, 1967.

"Error Bounds for Direct Solution of Linear Equations," by Professor D. B. Gillies, University of Illinois, Urbana, Illinois, March 21, 1967.

11.4 Colloquia

"The Busy Beaver Problem and Computational Complexity," by Professor Fred Hennie, Massachusetts Institute of Technology, Cambridge, Massachusetts, January 9 and 10, 1967.

"An Adaptive Tree Pruning System for Heuristic Programming of Trial and Error Search," by Mr. E. W. Kozdrowicki, Department of Electrical Engineering, University of Washington, Seattle, Washington, February 6, 1967.

"Recent Papers on the Reduction of Automata," by Professor Franz E. Hohn, Department of Mathematics, University of Illinois, Urbana, Illinois, February 20, 1967.

"The Electrical Character of Interconnections for Subnanosecond Integrated Circuits," by Professor Henry Guckel, Department of Electrical Engineering, Washington University, St. Louis, Missouri, February 27, 1967.

"The Impact of Batch Fabricated Components on Engineers and Engineering," by Mr. Rex Rice, Manager, Digital Systems Research Department, Fairchild Semiconductor, Palo Alto, California, March 6, 1967.

"On the Structure and Transition Preserving Functions on Automata," by Professor Zamir Bavel, Department of Mathematics, Southern Illinois University, Carbondale, Illinois, March 13, 1967.

"The ILLIAC III Computer Project," by Professor Bruce H. McCormick, Department of Computer Science, University of Illinois, Urbana, Illinois, March 20, 1967.

11.5 Drafting

During the quarter, the following drawings were processed by both drafting sections:

	General	Pattern Recognition
Large Drawings	18	39
Medium Drawings	189	104
Small Drawings	57	46
Layouts	2	176
Report Drawings	0	38
Changes	12	33
Semiconductor Coding	0	46 hours
Miscellaneous	28	7

(M. Goebel, J. Otten)

11.6 Shops' Production

Job orders processed and completed during the first quarter of 1967, are as follows:

Facility	State 300	AEC 1018	AEC 1469	Other
Machine Shop	25	38	11	4
Electronics Shop		72	5	
Etch Shop	6	37	7	
Layout Shop	2	18	7	

Wiring of 1760 standard printed circuit boards during this period, accounted for 115,283 diodes and 26,317 transistors, and 702 1018-1664 Mother Board Assemblies were assembled.

(Frank P. Serio)

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COO-1469-0072

QUARTERLY TECHNICAL PROGRESS REPORT

April, May, June, 1967

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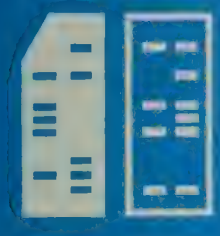

DEPARTMENT OF COMPUTER SCIENCE · UNIVERSITY OF ILLINOIS · URBANA, ILLINOIS

QUARTERLY TECHNICAL PROGRESS REPORT

April, May, June, 1967

Department of Computer Science
University of Illinois
Urbana, Illinois 61801

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1. CIRCUIT RESEARCH PROGRAM

(Supported in part by the Office of Naval Research under Contract NR 048-102/6-15-67(Code 437).

Summary

The Paramatrix slide scanner has been built and is working in a temporary mechanical mount; circuits for driving the CRT are described by Larry Ryan. Dick Koo presents a more tractable analysis of the operation of a photoconductor subjected to a train of light pulses, and applies his conclusions to an improved version of the Photoconductive Matrix. In the area of Random Sequence Coding Chushin Afuso presents a theoretical analysis of the "subtracter by direct subtraction" sustained by data from an experimental unit. John Esch shows how a single stochastic computing element may be made to perform all the elementary arithmetic operations on a pair of clocked random pulse sequences. Minor changes to Phastor are described by Larry Wallman. The Geomatrix report, by Bill Steiner, is mainly devoted to the autonomous read and write circuits to be placed at node points of the system's resistive grid. Finally, Michael Payne outlines an approach to the problem of graphic display based on representing curve segments by polynomials of various sorts.

1.1 PARAMATRIX (Project No. 01)

1.1.1 Introduction

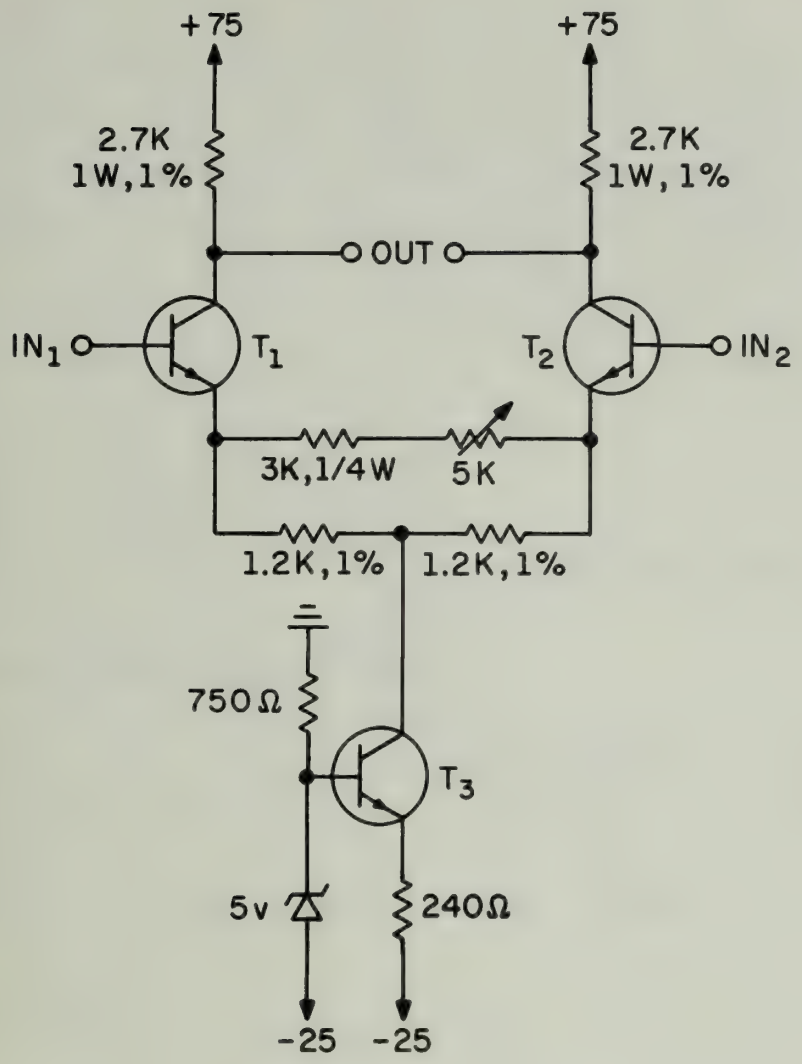
A simple scanning method, incorporating both horizontal and vertical control, is discussed. All the circuitry, except for the photo-multiplier detection circuit, has been designed and tested. Two of the circuits are presented here.

Mechanical mounts for the CRT and photo-multiplier, to be used in a temporary breadboard set-up, have been constructed. The final pieces of equipment required for the slide scanner arrived during June.

1.1.2 Scanning System

The new scanning system makes use of the fact that X and Y, the analog outputs of the Transformer, correspond to the coordinates of a test point on the input slide (transparent lines on a dark background). To determine whether or not this point is part of the input pattern, amplified versions of X and Y are fed to the horizontal and vertical deflection plates of the CRT to deflect the electron beam to the appropriate point on the slide. Thus, the presence of light behind the slide would indicate that the test point is a part of the input pattern. Conversely, the absence of light behind the slide would mean that the test point is not a part of the input pattern.

It was desired that variable horizontal and vertical sensitivity controls be included in the scanning system so that analog levels (X, Y) that correspond to points "near" line segments of the input pattern would be considered as being part of the input pattern. This is accomplished by superimposing voltage waveforms on the amplified versions of both X and Y. A linear ramp, symmetrical about ground, is added to X, and a sine wave is added to Y. The necessary addition and amplification are performed by a differential amplifier which is shown in Figure 1. It is a standard differential amplifier with the 5K potentiometer in the emitter circuit providing a gain variation from 3 to 4.



T_1, T_2 = RCA 40327

T_3 = 2N1613

All resistors 1/2 W 5% carbon unless specified.

Figure 1. Differential Amplifier.

It was anticipated that the undeflected CRT beam would not fall on the geometric center of the CRT screen. Thus, it was necessary to add adjustable D.C. voltages to both the horizontal and vertical deflection waveforms. This was accomplished by means of a simple resistor summing circuit shown in Figure 2.

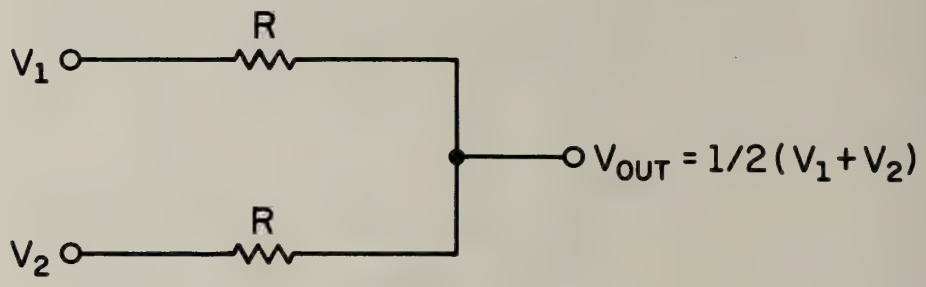
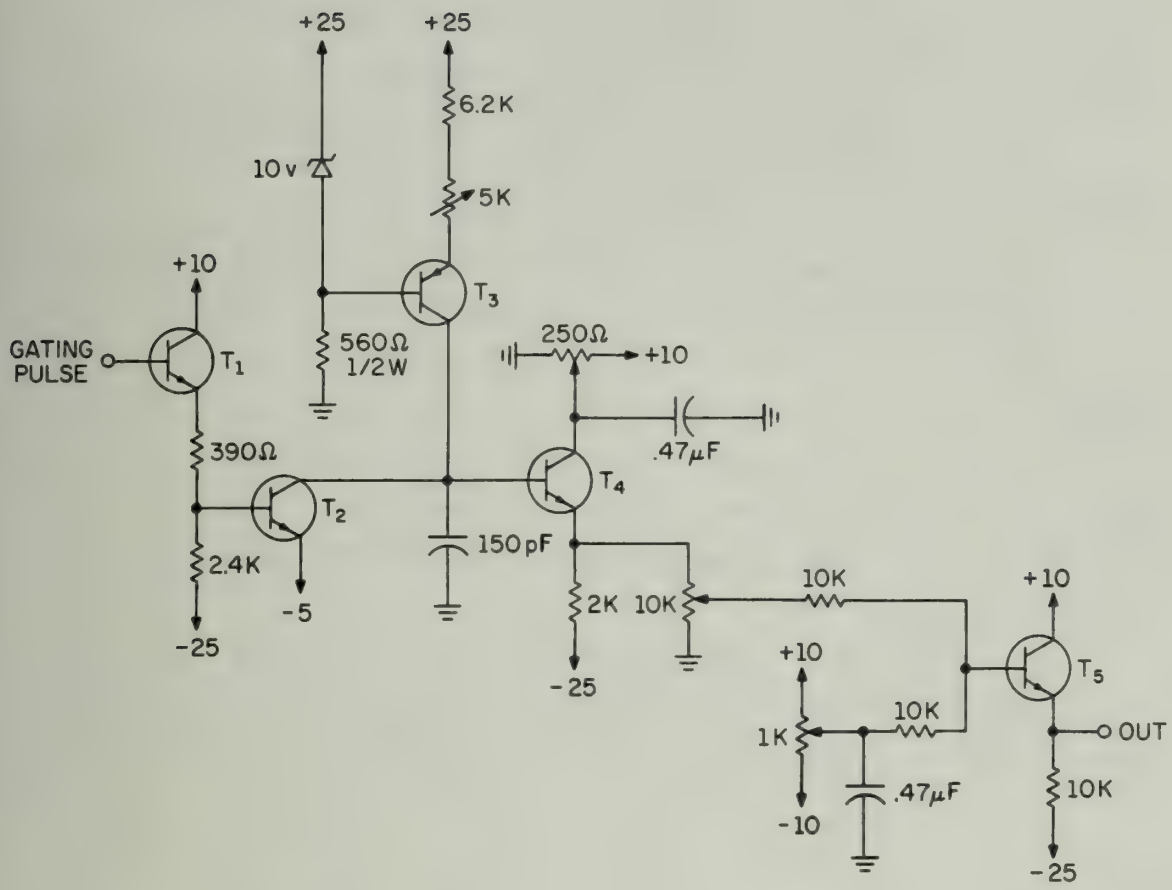


Figure 2. Resistor Summing Circuit.

The complete ramp generator and D.C. balance circuit is shown in Figure 3. The input to the circuit is a gating pulse that switches from ground to -5 volts to initiate the ramp, and from -5 volts to ground to turn the ramp off.

If the ramp circuit input has been at ground for a short time, the base of T_2 tries to go to -3.5 volts and T_2 saturates. The constant current of about 1.5ma supplied by T_3 flows through T_2. Thus, the output of T_4 is slightly below -5 volts. A fraction of this voltage (as determined by the 10k potentiometer, the horizontal sensitivity control) is added to the D.C. balance voltage (set by the 1k potentiometer) and the sum (attenuated by a factor of 1/2) feeds the emitter follower T_5. The output of the emitter



T_1, T_2, T_4 = 2N1308

T_3 = 2N1309

T_5 = 2N706A

All resistors 1/4 W 5% carbon unless specified

Figure 3. Ramp Generator and D.C. Balance

follower drives one input to the differential amplifier (for horizontal deflection).

If the ramp circuit input switches from ground to -5 volts, the base of T_2 goes to -8 volts and T_2 is cut-off. The constant current of 1.5 ma switches from T_2 and begins to charge up the 150pF capacitor. The capacitor voltage increases linearly from -5 volts until T_4 saturates. The voltage at which T_4 saturates is adjusted by the 250Ω potentiometer so that the ramp swing is symmetric about ground.

When the ramp circuit input switches from -5 volts to ground, T_2 saturates again and the output of T_4 returns to -5 volts.

Errata

The following errors were found in Section 1.1.3 of the Quarterly Technical Progress Report for January-March, 1967.

In the first paragraph, "long" should read "short", and "50μs" should read "50ns".

In the third (final) paragraph, the first sentence should read: "A photomultiplier has to be used, because of the poor response of semiconductor light-sensitive devices to the blue P-16 phosphor".

L. D. Ryan

1.2 PHOTOCONDUCTIVE MATRIX (Project No. 02)

1.2.1 Introduction

An equivalent circuit for a photoconductor, subjected to a train of light pulses, has been developed. Based upon this equivalent circuit an improved matrix structure has been found, which allows a larger matrix than was originally thought possible.

It has been observed that the time taken by the galvanometer mirror to move through a given angle is nearly proportional to this angle. The long transient at large deflecting angles limits the system scanning speed, and means of surmounting this obstacle are being considered. A new scanning sequence, that allows a higher scan repetition frequency, is proposed.

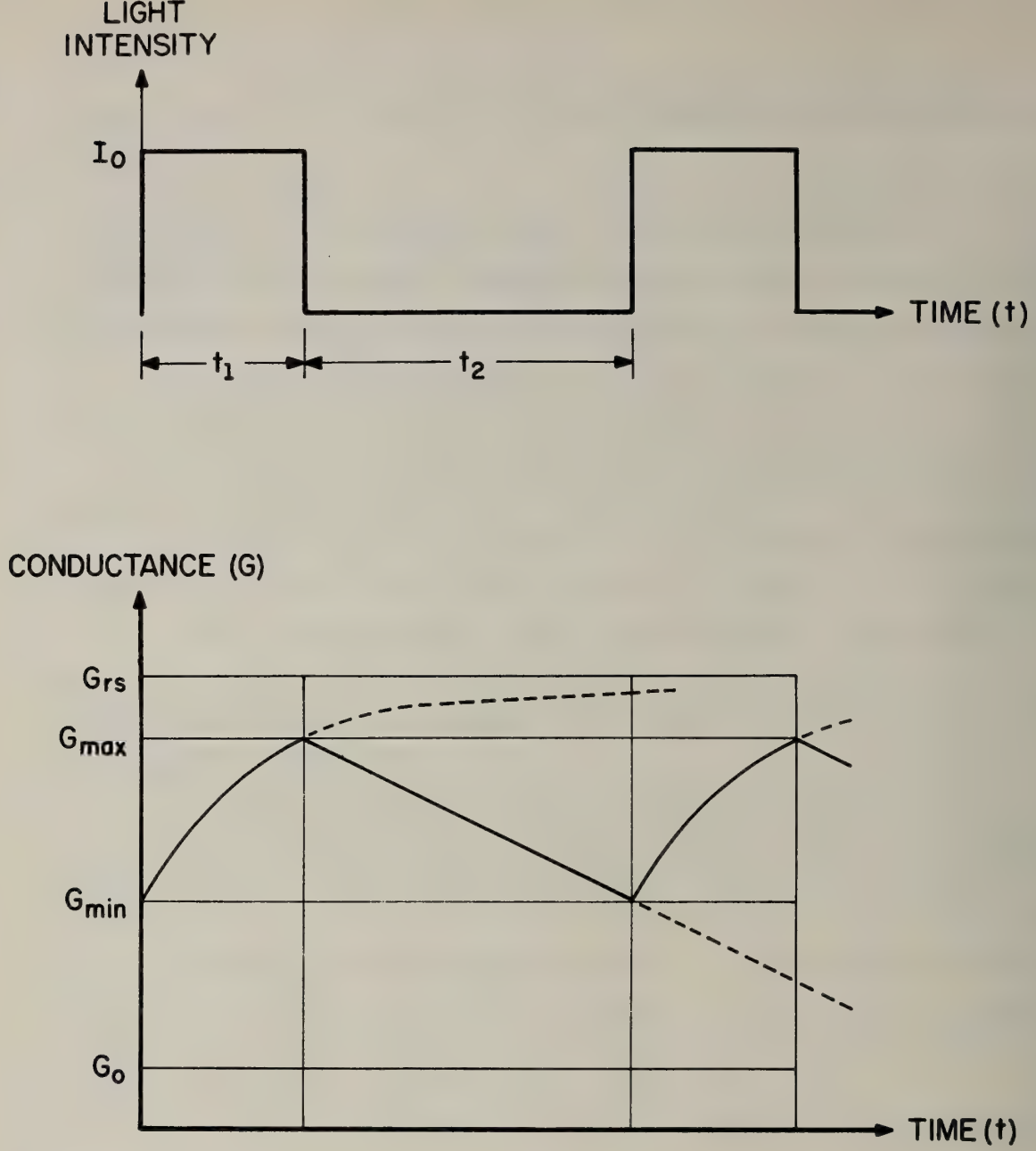
1.2.2 Photoconductor Excited by Pulsed Light - Steady State Equivalent Circuit

As mentioned in previous reports, the cell response time to pulsed light depends on both the light intensity and the cell material. An analytic approach, based on the single trap level model, leads to a time-dependent equation that is not readily solved. But a reasonable approximation to the experimentally observed behavior (Figure 1) is to assume that the cell conductance follows an exponential law, with rise and fall times distinguished by different time constants.

Using this approximation and the notation of Figure 1, the response (conductance) function, G(t) is given by:

$$G(t) = G_{rs} - (G_{rs} - G_{min})e^{-\alpha_1 t_1}; \quad 0 \leq t \leq t_1 \qquad (1)$$

$$G(t) = G_0 + (G_{max} - G_0)e^{-\alpha_2 (t - t_1)}; \quad t_1 \leq t \leq t_1 + t_2 \qquad (2)$$



G_{rs} = DC conductance with light intensity I_0;

G_0 = DC conductance with zero light intensity;

G_{max}, G_{min} = upper, lower bounds of AC conductance.

Figure 1. Steady State Response to Periodic Light Pulse Train.

where α_1 and α_2 are, respectively, the reciprocal rise and fall time constants. The continuity equations determining G_{max} and G_{min} are readily seen to be:

$$\frac{G_{max} - G_0}{G_{rs} - G_0} = \frac{1-e^{-\alpha_1 t_1}}{1 - e^{-\alpha_1 t_1 - \alpha_2 t_2}} \tag{3}$$

$$\frac{G_{rs} - G_{min}}{G_{rs} - G_0} = \frac{1 - e^{-\alpha_2 t_2}}{1 - e^{-\alpha_1 t_1 - \alpha_2 t_2}} \tag{4}$$

The total effective conductance may be separated into DC and AC components by standard Fourier techniques:

$$G(t) = \sum_{n=-\infty}^{\infty} g_n e^{i\beta_n t} \tag{5}$$

$$g_n = \frac{1}{T} \int_0^T G(t) e^{-i\beta_n t} \tag{6}$$

where $T = t_1 + t_2$ and $\beta_n = 2n\pi/T$. Substituting (1) and (2) in (6) yields:

$$Tg_n = \frac{G_{rs}}{i\beta_n}\left(1 - e^{-i\beta_n t_1}\right) - \left(\frac{G_{rs} - G_{min}}{\alpha_1 + i\beta_n}\right)\left(1 - e^{-(\alpha_1 + i\beta_n)t_1}\right)$$

$$+ e^{-i\beta_n t_1}\,\frac{G_0}{i\beta_n}\left(1 - e^{-i\beta_n t_2}\right) + \left(\frac{G_{max} - G_0}{\alpha_2 + i\beta_n}\right)\left(1 - e^{-(\alpha_2 + i\beta_n)t_2}\right) \qquad (7)$$

The DC component may be obtained by setting $\beta_n = 0$ in (7), and, using (3) and (4), is given by:

$$Tg_0 = t_1 G_{rs} + t_2 G_0 + 2\left(\frac{1}{\alpha_2} - \frac{1}{\alpha_1}\right)(G_{rs} - G_0)\,\frac{\sinh\left(\frac{\alpha_1 t_1}{2}\right)\sinh\left(\frac{\alpha_2 t_2}{2}\right)}{\sinh\left(\frac{\alpha_1 t_1 + \alpha_2 t_2}{2}\right)} \qquad (8)$$

In general, the amplitude of the n^{th} harmonic is $2|g_n|$. For the photoconductors currently being used G_0 is about eight orders of magnitude smaller than G_{rs} and may therefore be neglected. Figure 2a is a plot of the (normalized) g_0, as given by (8), as a function of α_1/α_2, with t_2/t_1 as a parameter. Figure 2b shows the ratio of the first harmonic amplitude ($2|g_1|$) to g_0 as a function of α_1/α_2, again with t_2/t_1 as a parameter.

For the purpose of developing an equivalent circuit, it is convenient to write the Fourier expansion (5) as the sum of a DC and an AC term, thus:

$$G(t) = g_0 + \sum_{n \neq 1} g_n e^{i\beta_n t} = g_0 + g_{AC}, \text{ say}$$

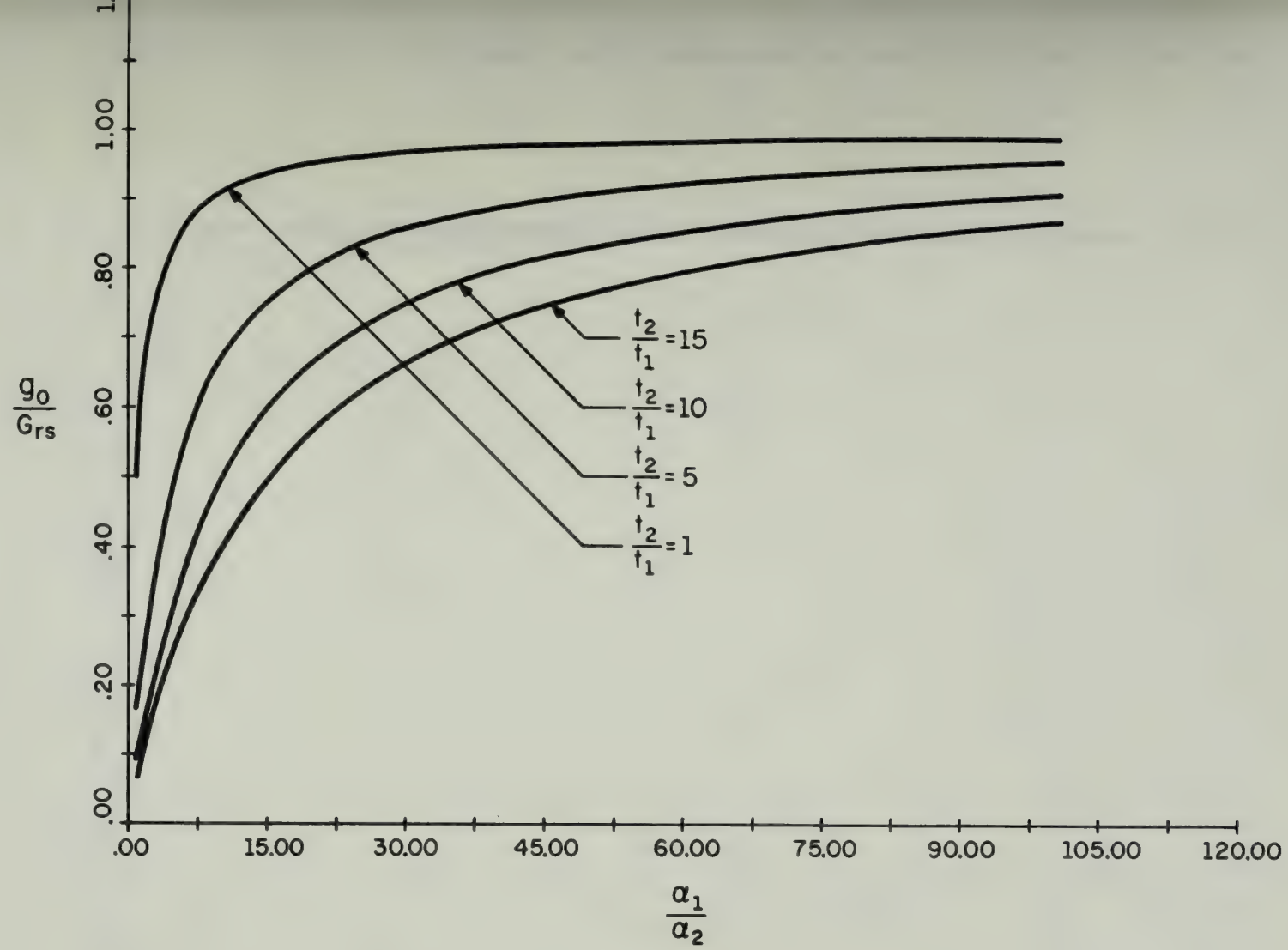


Figure 2a. DC Conductance as Function of Time Constant Ratio.

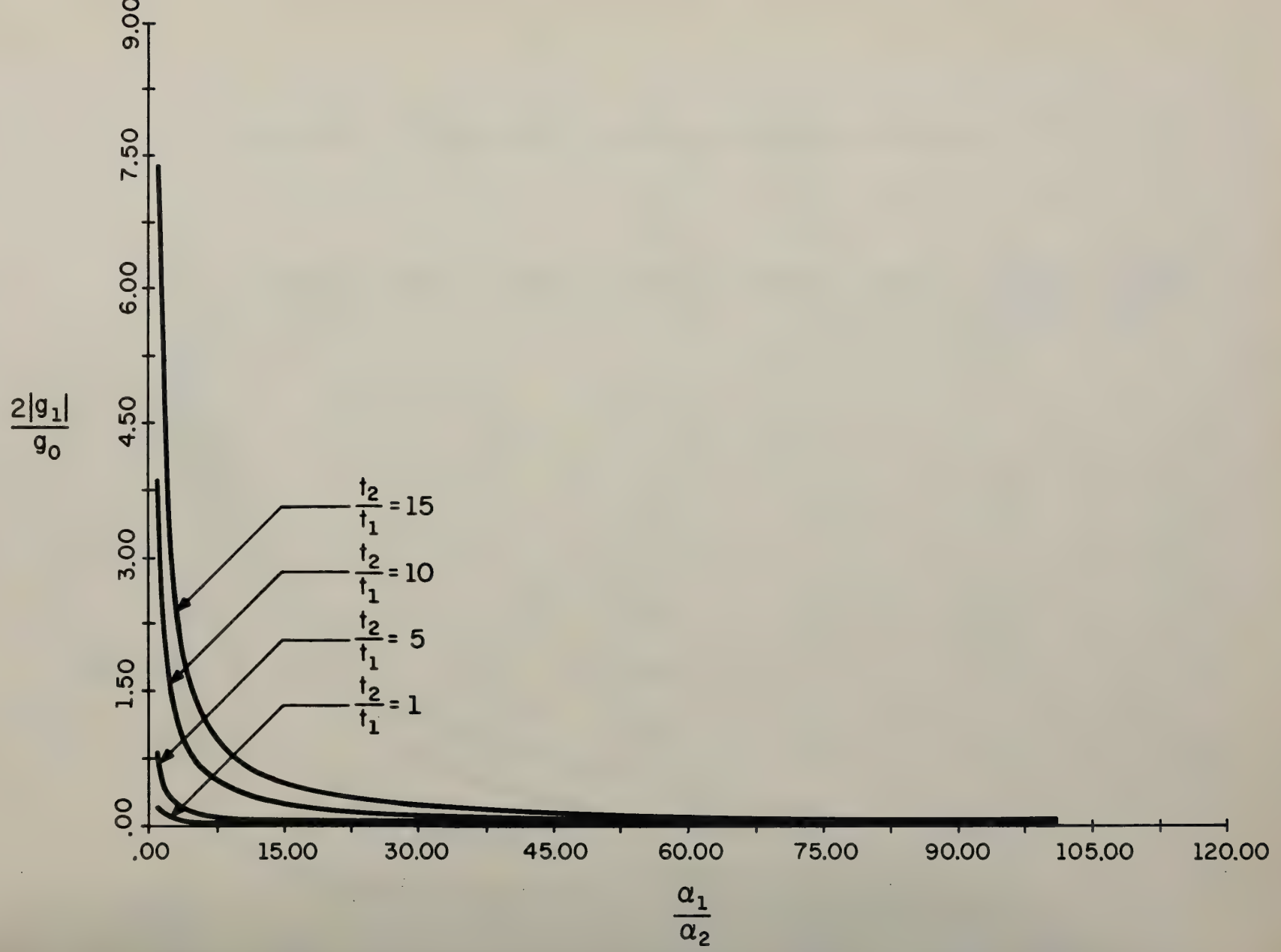


Figure 2b. Ratio of 1st Harmonic to DC Conductance as Function of Time Constant Ratio.

The current-voltage relation for the photoconductor is then:

$$I = (1 + \mu)\, g_0 V \qquad (9)$$

with $\mu = g_{AC}/g_0$. Figure 3 shows a voltage (b) and current (c) source equivalent circuit for the simple arrangement (a).

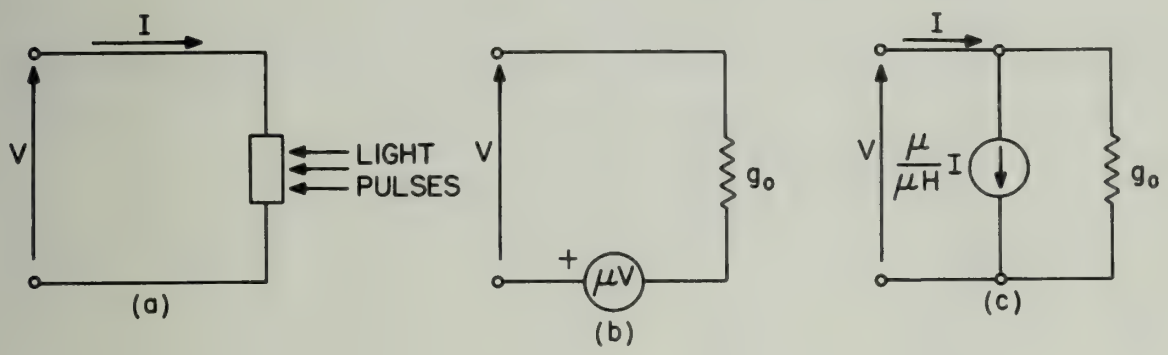


Figure 3. Photoconductor Circuit (a),
Voltage Equivalent Circuit (b),
Current Equivalent Circuit (c).

1.2.3 Connection of Matrix

As has been noted in a previous report, the dimensions of the matrix are limited by the cross-talk and noise resulting from the fluctuating conductances. The T-connection, described below, eliminates much of the cross-talk and allows a larger matrix to be used.

Three photoconductors are used to form each matrix connection, as shown in Figure 4, while Figure 5 shows the physical layout and a typical scan path.

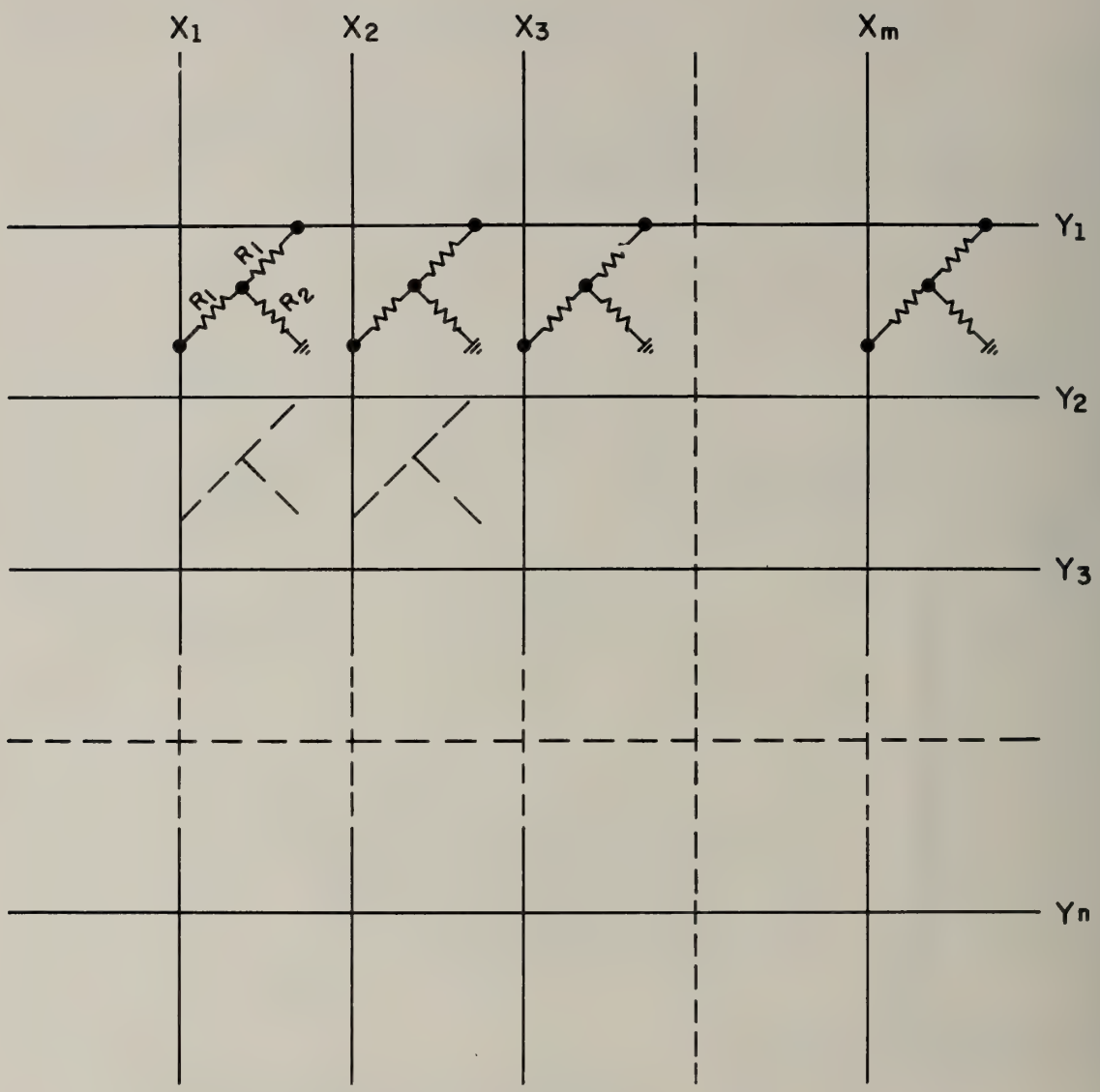


Figure 4. T-connected Matrix.

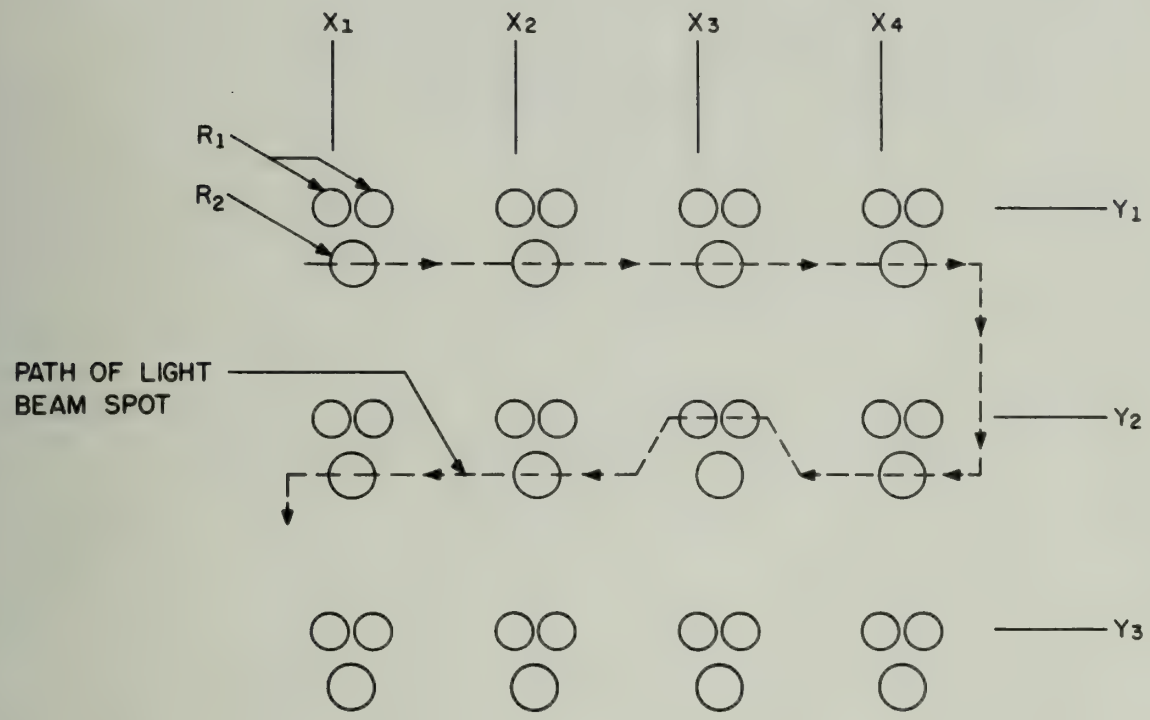


Figure 5. Scan Path for X_3 - Y_2 Connection.

$$\frac{R_d}{R_{av}} = 1000 \qquad (m = 1000)$$

$$\frac{R_{av}}{R_L} = 10^{-2}$$

Then

$$\Theta = 82\%$$

$$\Omega = 1.64 \times 10^{-6}$$

The noise generated by the fluctuating conductances may be found from Figure 6 by considering only the equivalent current sources. The result is:

$$V_{ns} = \mu\Theta\,(1 - \Theta)\left\{ \left[1 + \frac{\Omega(m - 1)}{1 - \Theta} \right] V_i + \frac{\Omega}{\Theta} \sum V_r \right\}$$

Considering the typical case where Ω is small and the V_r's are of the same order:

$$V_{ns} \simeq \mu\Theta\,(1 - \Theta)\left[1 + \frac{\Omega(n - 1)}{1 - \Theta} \right] V_i$$

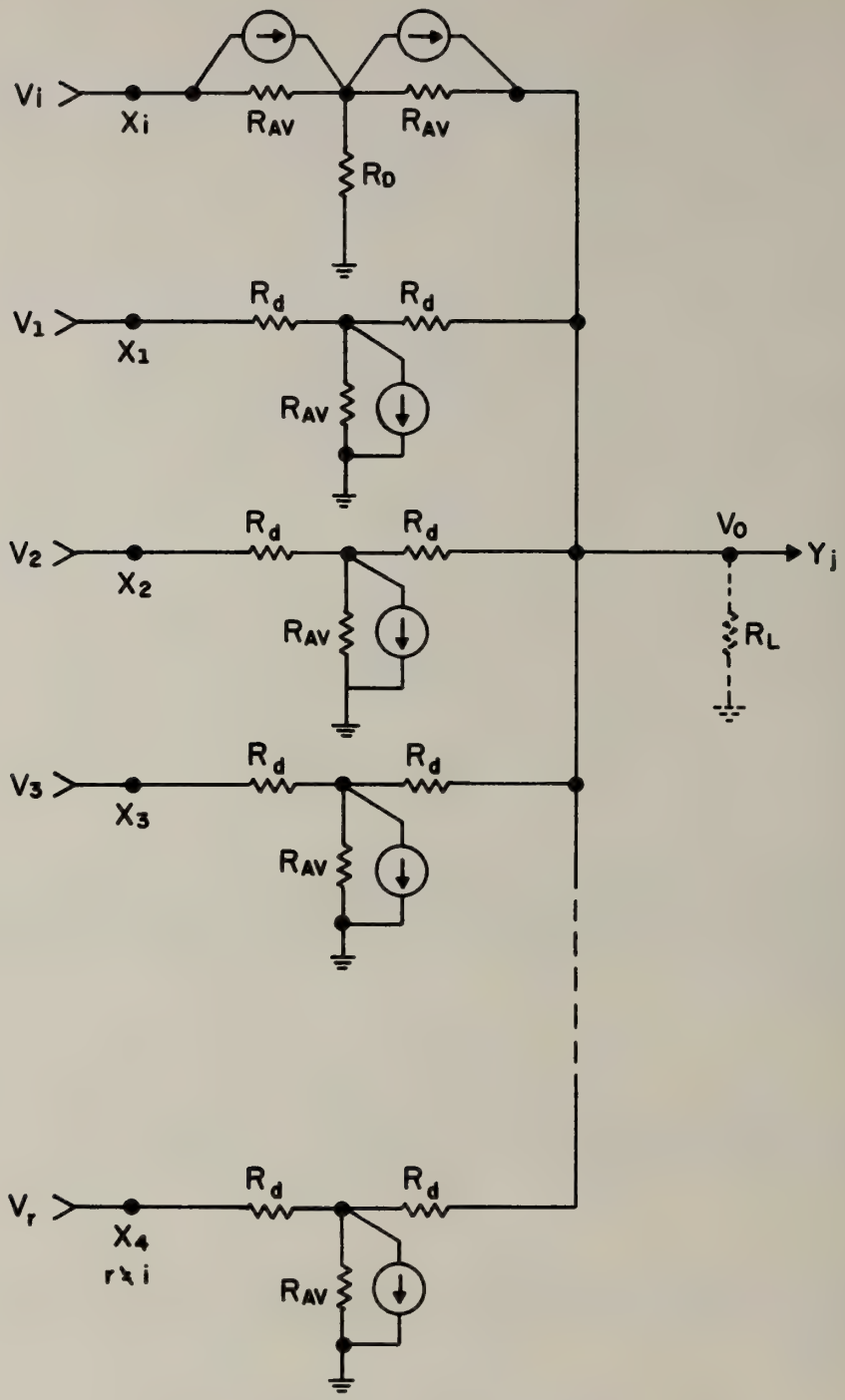


Figure 6. Equivalent Circuit for Typical Scan Path.

Defining a noise figure as $\frac{V_{ns}}{V_0}$, one finds

$$NF = \frac{V_{ns}}{V_0} = \mu(1 - \Theta) \quad 1 + \frac{\Omega(n - 1)}{1 - \Theta} \quad \underset{\sim}{\sim} \mu(1 - \Theta)$$

Filling in some numerical values as was done above, and using μ for the first harmonic of 0.05, the noise figure is found to be

$$NF \underset{\sim}{\sim} 0.01$$

1.2.4 Light Beam Scanning

It has been found experimentally that the deflecting mirror requires a time proportional to its angle of deflection, to reach a steady position (Figure 7). This phenomenon makes the original scanning sequence, shown in Figure 8, unacceptable. In this system, the light spot takes much longer to move from position B to C, than from A to B. Thus, with the deflector driven by a constant step width staircase wave form, as shown in Figure 9, the spot spends less time at C than at B, due to the relatively long flight B to C. Photoconductors to the left of the matrix thus receive less photo energy per cycle and the matrix excitation is spatially uneven.

Also, at higher scan frequencies the deflector does not have time to reach C from B and the rest spot is displaced to C' as shown by the dotted circle in Figure 8. In a given deflection system, the distance BC limits the scanning frequency and thus becomes a serious handicap for larger arrays.

To reduce the disadvantage created by the transient property of the deflecting mirror, an interlace scanning is suggested, as shown in Figure 10. In this scheme it is obvious that the limiting factor will be the path length EF, which is independent of the dimensions of the matrix and is evidently much smaller than the distance BC in Figure 8. Since EF could be the same as DE if the columns and rows

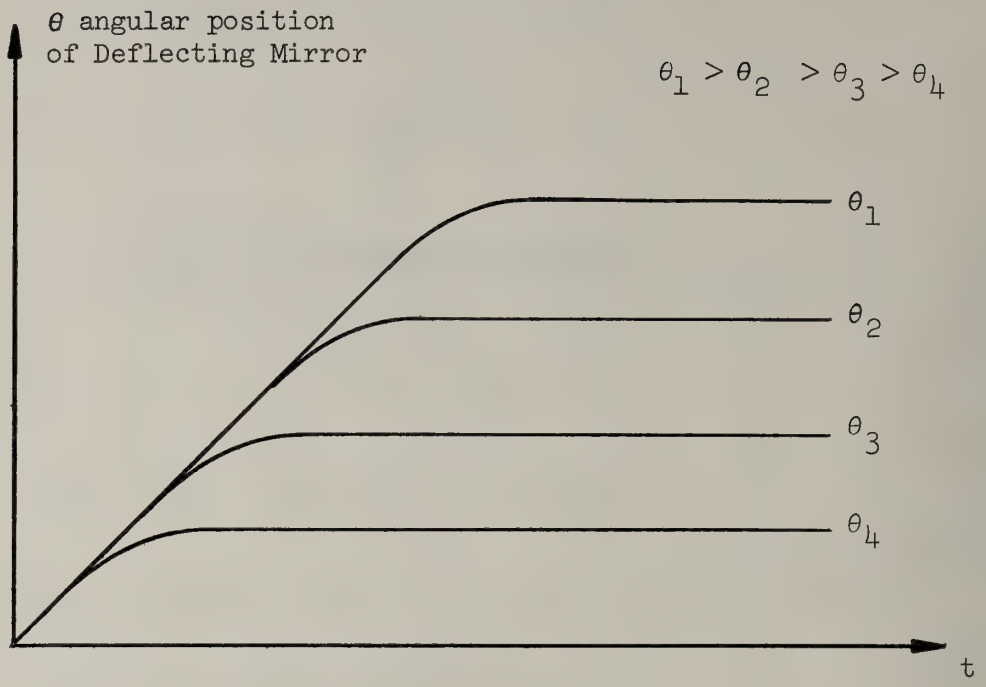


Figure 7. Response of Deflecting Mirror.

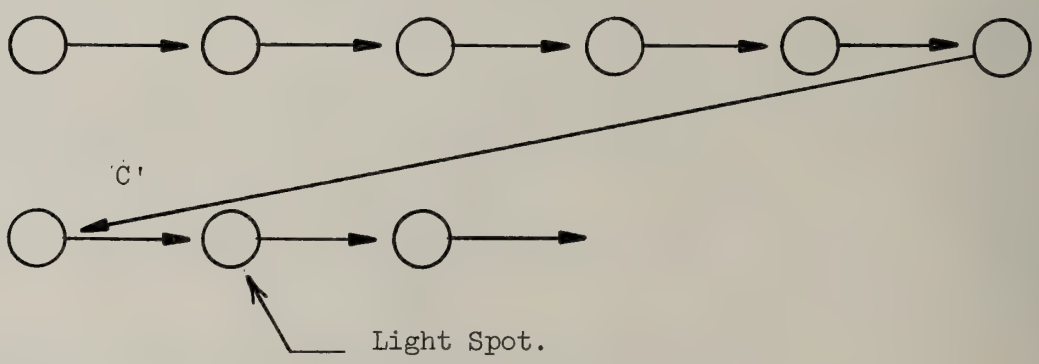


Figure 8. Original Scanning Sequence.

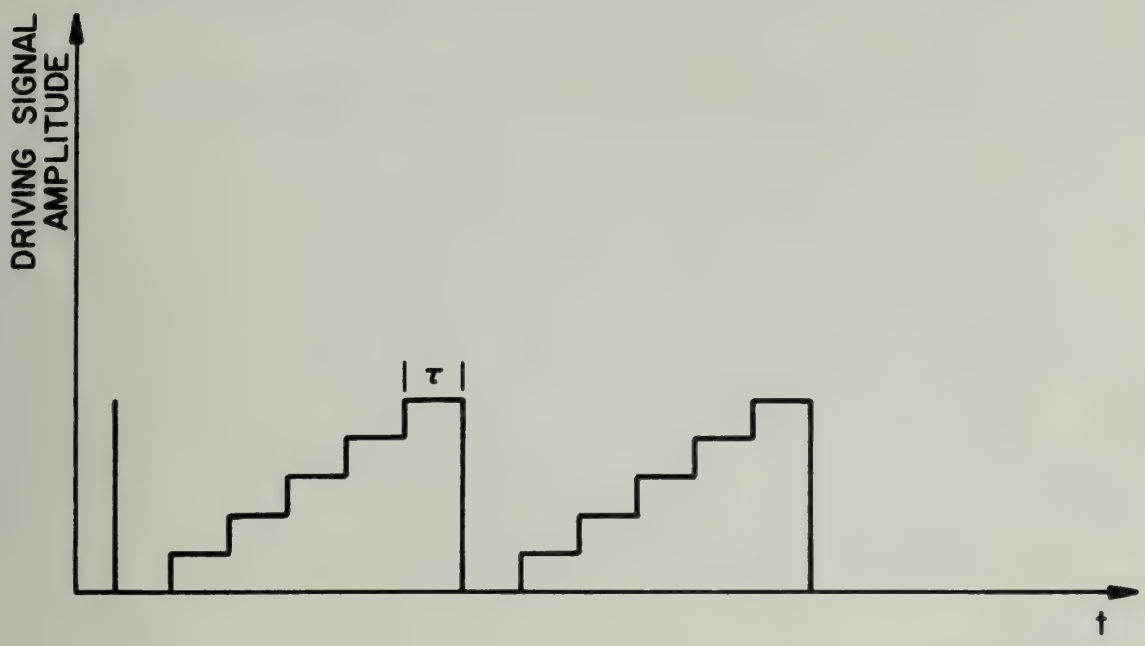


Figure 9. Galvanometer Drive Signal

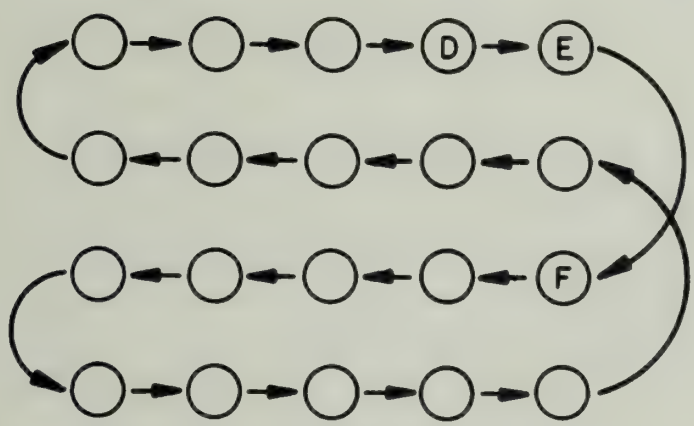


Figure 10. Revised Scanning Sequence

are properly arranged, a spatially uniform excitation and higher scanning frequency can be achieved.

Tuh-Kai Koo

1.3 RANDOM SEQUENCE CODING (Project No. 03)

1.3.1 The Higher Order Subtracter by Direct Subtraction (Deletion Method)

In the last quarterly report the first order subtracter was treated. Now the same treatment is extended to the higher order approximation. We begin with a theoretical analysis.

Let A and B denote the minuend and subtrahend (synchronous) clocked random pulse sequences with probabilities a and b, respectively.

In the subtracter by direct subtraction (deletion method) the resultant sequence, C, is formed from the minuend sequence, A, by deleting pulses each of which corresponds to every pulse of the subtrahend sequence, B. As the r^{th} order approximation of this operation, the r^{th} order subtracter has the following functions:

(1) Those pulses of A and B which coincide with each other are deleted, and new sequences A' and B' which no longer have coincident pulses are obtained.

(2) The temporary storage (up-down counter) can store r pulses of B' sequence. If more pulses of B' sequence than that can be stored in the temporary storage occur, they are discarded and thereby produce an error.

The precise analysis of such a unit is complicated and unpractical. However, the accuracy can be estimated in a relatively simple manner with a simplified mathematical model.

As before, an element of time interval is defined as shown in Figure 1. It has n blanks following a pulse of A and has one pulse at the end, n = 0, 1, 2, ...

For the sake of simplicity of analysis, let us assume that the temporary storage (up-down counter) can store r' pulses of the B sequence at any time.

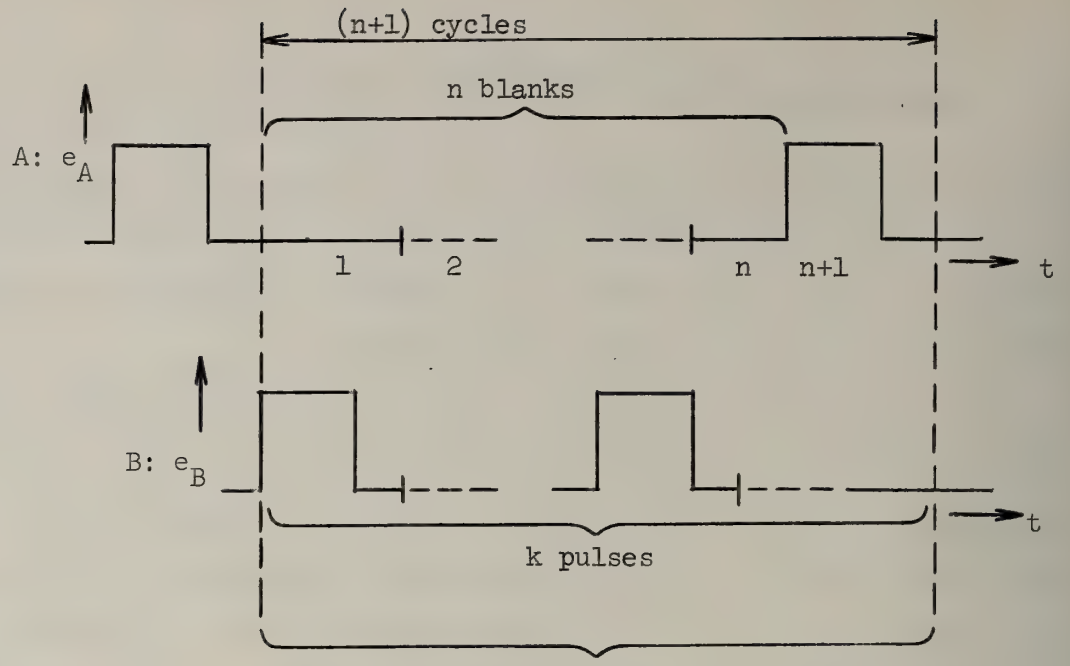


Figure 1. Correspondence of the Minuend and Subtrahend Sequences and an Element of Time Interval.

Note that even when the temporary storage can store r pulses at the maximum it does not mean that it can accept r pulses at any time, because there are some carried-over pulses which have not yet been used for deleting A-pulses. Apparently $r' < r$.

Let the number of B-pulses in the element of time interval be k; then if $k \leq r'$, all k pulses of B are effective in deleting k pulses of A. If $k > r'$, only the first r' pulses of B are effective for deletion. By assuming the binomial for the pulse distributions of random pulse sequences, we have:

$$P\left\{\text{a B-pulse is effective in deleting an A-pulse} \mid \text{a time interval element of A sequence with n blanks}\right\}$$

$$= \sum_{k=1}^{r'} k\binom{n+1}{k} b^k (1-b)^{n+1-k} + r' \sum_{k=r'+1}^{n+1} \binom{n+1}{k} b^k (1-b)^{n+1-k}$$

$$= \sum_{k=1}^{n+1} \binom{n+1}{k} b^k (1-b)^{n+1-k}$$

$$+ \sum_{k=2}^{r'} (k-1)\binom{n+1}{k} b^k (1-b)^{n+1-k} + (r'-1) \sum_{k=r'+1}^{n+1} \binom{n+1}{k} b^k (1-b)^{n+1-k}$$

$$= \left[1 - (1-b)^{n+1}\right] + \left[1 - (1-b)^{n+1} - (n+1)\, b\, (1-b)^n\right]$$

$$+ \left[1 - (1-b)^{n+1} - (n+1)\, b\, (1-b)^n - \frac{(n+1)n}{2} b^2 (1-b)^{n-1}\right] + \ldots.$$

$$\ldots. + \left[1 - (1-b)^{n+1} - \ldots. - \binom{n+1}{r'-1} b^{r'-1} (1-b)^{n-r'+2}\right] \qquad (1)$$

Also

$$P\left\{\text{a time interval element of A sequence with n blanks occurs}\right\}$$

$$= a(1-a)^n \qquad (2)$$

For each such element of time interval, one A-pulse is deleted. Therefore the effective subtrahend $b_{r'}$ is,

$$b_{r'} = a \sum_{n=0}^{\infty} a(1-a)^n \left[\sum_{k=1}^{r'} k \binom{n+1}{k} b^k (1-b)^{n+1-k} + r' \sum_{k=r'+1}^{n+1} \binom{n+1}{k} b^k (1-b)^{n+1-k} \right] \qquad (3)$$

For the sake of simplicity of calculation, consider $b_{r'}$ and $b_{r'-1}$ which are given by,

$$b_{r'} = a^2 \sum_{n=0}^{\infty} (1-a)^n \left[\left\{ 1 - (1-b)^{n+1} \right\} + \ldots + \left\{ 1 - (1-b)^{n+1} - \ldots - \binom{n+1}{r'-1} b^{r'-1} (1-b)^{n-r'+2} \right\} \right]$$

and

$$b_{r'-1} = a^2 \sum_{n=0}^{\infty} (1-a)^n \left[\left\{ 1 - (1-b)^{n+1} \right\} + \ldots + \left\{ 1 - (1-b)^{n+1} - \ldots - \binom{n+1}{r'-2} b^{r'-2} (1-b)^{n-r'+3} \right\} \right]$$

Let $\Delta b_{r'} = b_{r'-1}$, then

$$\Delta b_{r'} = a^2 \sum_{n=0}^{\infty} (1-a)^n \left\{ 1 - (1-b)^{n+1} - \ldots - \binom{n+1}{r'-1} b^{r'-1} (1-b)^{n-r'+2} \right\}$$

Also $$\Delta b_{r'-1} = a^2 \sum_{n=0}^{\infty} (1-a)^n \left\{ 1 - (1-b)^{n+1} - \ldots - \binom{n+1}{r'-2} b^{r'-2} (1-b)^{n-r'+3} \right\}$$

$$\therefore \Delta b_{r'} - \Delta b_{r'-1} = a^2 \sum_{n=0}^{\infty} (1-a)^n \binom{n+1}{r'-1} b^{r'-1} (1-b)^{n-r'+2}$$

$$= - \frac{a^2 (1-a)^{r'-2} b^{r'-1}}{r'!} \sum_{n=0}^{\infty} (n+1)n \ldots (n-r'+2) \left\{ (1-a)(1-b) \right\}^{n-r'+2}$$

It can be shown that

$$\sum_{n=0}^{\infty} (n+1)n \ldots (n-r'+2) \left\{ (1-a)(1-b) \right\}^{n-r'+2} = \frac{(r'-1)!}{\left\{ 1-(1-a)(1-b) \right\}^{r'}}$$

Hence:

$$\Delta b_{r'} - \Delta b_{r'-1} = -b \frac{1}{\left\{1+b(1/a-1)\right\}^2} \left[\frac{b(1/a-1)}{1+b(1/a-1)}\right]^{r'-2}$$

$$\Delta b_{r'} = \Delta b_{r'-1} - b \frac{1}{\left\{1+b(1/a-1)\right\}^2} \left[\frac{b(1/a-1)}{1+b(1/a-1)}\right]^{r'-2}$$

Let $\frac{1}{1+b(1/a-1)} = \xi$, $\frac{b(1/a-1)}{1+b(1/a-1)} = \eta$ (4)

then $\Delta b_{r'} = \Delta b_{r'-1} - b\,\xi^2\eta^{r'-2}$

$= \Delta b_{r'-2} - b\,\xi^2\eta^{r'-3} - b\,\xi^2\eta^{r'-2} = \ldots$

$\ldots = b_1 - b\,\xi^2(1 + \eta + \eta^2 + \ldots + \eta^{r'-2})$ (5)

Now $b_{r'} = (b_{r'} - b_{r'-1}) + (b_{r'-1} - b_{r'-2}) + \ldots + (b_2 - b_1) + b_1$

$= \Delta b_{r'} + \Delta b_{r'-1} + \ldots + \Delta b_2 + b_1$ (6)

Substitution of (6) into (5) yields,

$$b_{r'} = b_1 - b\,\xi^2\,(1 + \eta + \eta^2 + \ldots + \eta^{r'-2})$$

$$+ b_1 - b\,\xi^2\,(1 + \eta + \eta^2 + \ldots + \eta^{r'-3}) + \ldots + b_1$$

$$= r'b_1 - b\,\xi^2\left[(r'-1) + (r'-2)\,\eta + \ldots + 2\eta^{r'-3} + \eta^{r'-2}\right]$$

$$= r'b_1 - b\,\xi^2\left[r'(1 + \eta + \ldots + \eta^{r'-2})\right.$$

$$\left. - \{1 + 2\eta + 3\eta^2 + \ldots + (r' - 1)\eta^{r'-2}\}\right]$$

$$= r'b_1 - b\,\xi^2\left[r'\,\frac{1-\eta^{r'-1}}{1-\eta} - \frac{1-\eta^{r'-1}}{(1-\eta)^2} + \frac{r'-1}{1-\eta}\,\eta^{r'-1}\right]$$

$$= r'b_1 - \frac{b\xi^2}{1-\eta}\left[r' - \eta^{r'-1} - \frac{1-\eta^{r'-1}}{1-\eta}\right]$$

But $b_1 = a^2 \sum_{n=0}^{\infty} (1-a)^n \left[1-(1-b)^{n+1}\right] = \frac{b}{1+b(1/a-1)} = b\,\xi$

$$1 - \eta = \xi$$

$$\therefore\ b_{r'} = b\xi \left[r' - r' + \eta^{r'-1} + \frac{1-\eta^{r'-1}}{\xi} \right]$$

$$= b \left[1 - (1 - \xi)\eta^{r'-1} \right] = b(1-\eta^{r'})$$

$$= b \left[1 - \left\{ \frac{b(1/a-1)}{1+b(1/a-1)} \right\}^{r'} \right] \qquad (7)$$

As the result of subtraction we wish to have $c = a - b$, whereas (7) yields $a - b_{r'}$. Hence the error is always positive with respect to $a - b$, and given by

$$\varepsilon_{r'} = \left[\frac{b(1/a-1)}{1+b(1/a-1)} \right]^{r'} \qquad (8)$$

where ε is defined by the relation above.

The output of the subtracter = $a - b + \varepsilon b$.

1.3.2 Results of Experiments

The experimental logic circuits of the subtracter with $r = 7$ (3 binary stages as the up-down counter) are shown in Figure 2.

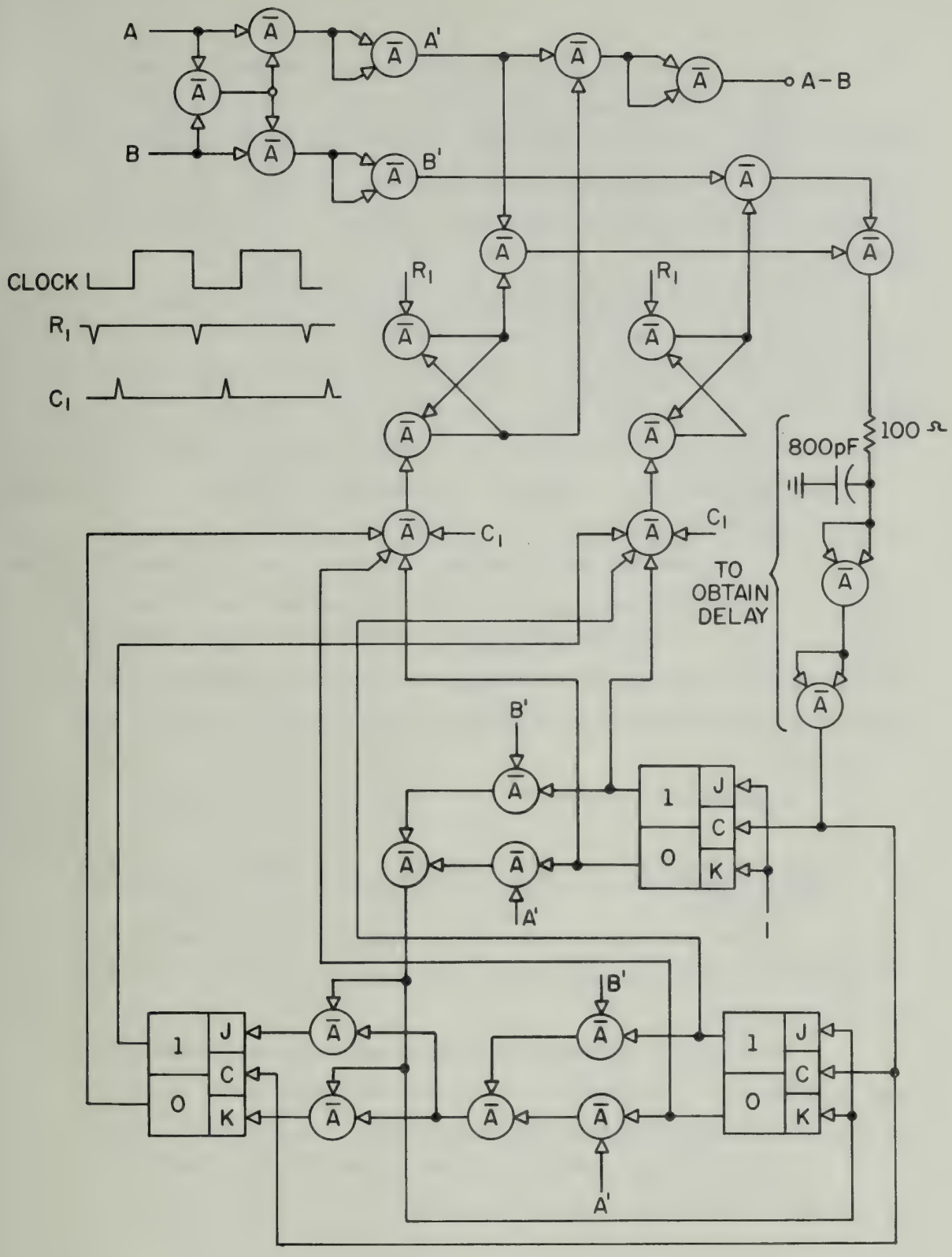


Figure 2. Experimental Logic Circuits of the Subtracter with a 3-stage Binary Counter as a Temporary Storage.

Some of the experimental results are tabulated in Table 1.

The clock of the system is 1MHz, and hence a = .100 corresponds to 100kHz, etc. The temporary storage can store 7 pulses at the maximum, i.e., r = 7 and C_7 is the output of the unit. ε_e is the measured error of the unit expressed in percent with respect to the subtrahend, b.

r' is the average capacity of the temporary storage, so to speak, which was defined for the mathematical model. The theoretical calculation of r' seems very complicated because of the storage effect. For practical purposes, however, only approximate values are sufficient. To find rough values of r' experimentally, measured values of ε_e and (8) are used. Numerical values of r' obtained in this manner are also tabulated in Table 1.

It is interesting to compare r = 7 and the experimental values of r'. As the subtrahend, b, increases and becomes comparable to the minuend, a, the instantaneous frequency of B often exceeds that of A. This means that the temporary storage is often occupied with B-pulses, and thus a smaller apparent capacity of the temporary storage than r = 7 results.

A design criterion of r' = r/2 would seem sufficient.

1.3.3 Determination of the Relative Magnitudes of the Minuend and Subtrahend.

So far we have assumed a > b. If a < b the order of the subtrahend and minuend, and at the same time the sign of the output, must be reversed.

To do this, the relative magnitudes of the two sequences must be compared. Fortunately this function takes place naturally in the up-down counter (temporary storage).

If a > b, the up-down counter is not full on the average. On the other hand, if a < b, the up-down counter is full most of

a	b	c_7	ε_e%	r'
.100	.010	.090	00	---
"	.020	.080	"	---
"	.030	.070	"	---
"	.040	.060	"	---
"	.050	.050	"	---
"	.060	.041	1.7	4.0
"	.070	.032	2.9	3.8
"	.080	.025	6.3	3.5
"	.090	.018	8.9	3.0
"	.100	.013	13.	2.8

a: Minuend

b: Subtrahend

c_7: Output of the subtracte

ε_e: Error of the subtracte

a	b	c_7	ε_e%	r'
.600	.060	.540	0	---
"	.120	.480	"	---
"	.180	.420	"	---
"	.240	.360	"	---
"	.300	.300	"	---
"	.360	.240	"	---
"	.420	.180	"	---
"	.480	.121	0.2	4.0
"	.540	.064	0.7	3.8

Table 1. Experimental Results of the Subtracter with a 3-Binary Stage Temporary Storage.

the time. Therefore by detecting the state of the up-down counter, the relative magnitudes of a and b are readily determined. The output of such a magnitude detector is used to control the steering gate of the subtracter, which controls the order of the minuend and subtrahend.

If $a = b$, this detecting scheme is still acceptable. The output of the detector would simply fluctuate between the two states, $a > b$ and $a < b$.

Chushin Afuso

1.3.4 Division

Division of numbers using a Clocked Random Pulse Sequence (CRPS) together with digital gates is perfectly feasible, contrary to the belief of some workers recently stated in the stochastic computer field. ["Random Pulse Machines", S. T. Ribeiro, I.E.E.E. Transactions on Electronic Computers, Vol. EC-16, page 264, June, 1967.]

To divide CRPS X by CRPS Y the procedure may be described briefly as follows:

(i) Each time an X-pulse occurs, the next Y-pulse is marked as the beginning of a timing interval, while the subsequent Y-pulse is the end of the timing interval.

(ii) During the timing interval all clock pulses, i.e., 'time slots', are counted.

(iii) The output is now a CRPS-Z, consisting of bunches of pulses spanning the counting interval, and this sequence now represents X/Y.

This may be verified as follows:

Consider a relatively long sampling time T. During T there will be n pulses in CRPS-X, where

$$n = T.\ (f_c.x)$$

f_c is the clock frequency

x is the probability of CRPS-X

also

$$x = \frac{f_x}{f_c}$$

where f_x is the average frequency of CRPS-X.

Now, the average period, S, of CRPS-Y is given by

$$S = \frac{1}{Y.f_c} \text{ since also } Y = \left(\frac{f_y}{f_c}\right)$$

This, by definition, is the counting interval and corresponds to $S.f_c$ pulses of the output sequence.

During T there will be n bunches of $S.f_c$ pulses. The output sequence, Z, then is

$$Z = \frac{f_z}{f_c}$$

$$= \frac{\text{Number of pulses in Z during T}}{T.f_c}$$

$$= \frac{nSf_c}{T.f_c} \qquad = \frac{nS}{T}$$

$$= \frac{T.f_c.X.S}{T}$$

$$= f_x \cdot S$$

$$= \frac{f_c X}{f_c Y} = \frac{X}{Y}$$

It should be noted that this can all be done with logic gates and flip-flops including a counter to keep track of statistical fluctuation where f_x may be larger than f_y.

In a stochastic computer this technique for division may be utilized when the CRPS-X is multiplied by a scale factor of 0.1 and restricting Y to the range 0.1 to 1.0.

The same technique as that outlined above will work, if the counting interval is taken from the beginning of the first CRPS-Y pulse to the beginning of its next pulse.

Figure 3 shows a schematic of the system described above.

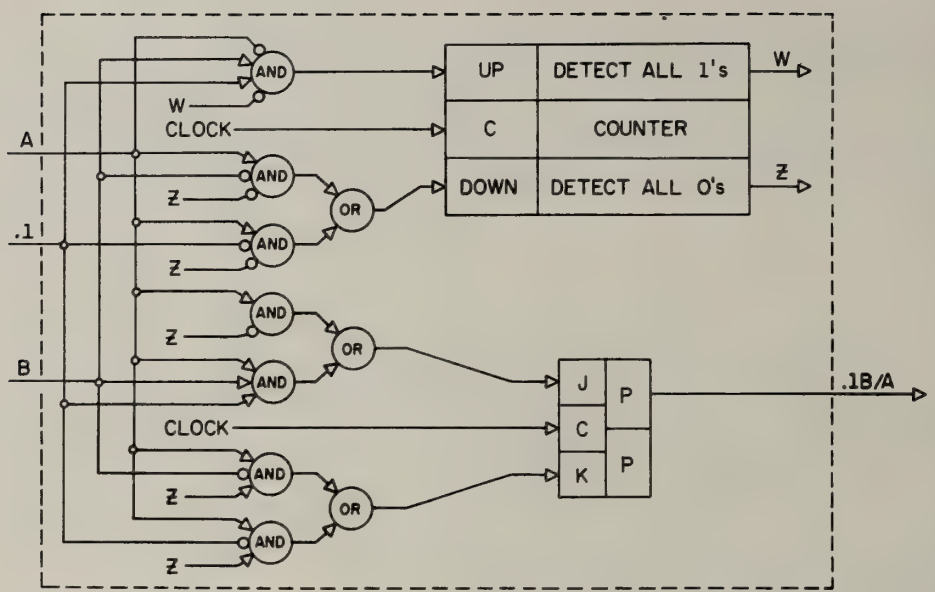


Figure 3. Division of CRPS-X and CRPS-Y and Scaling.

A Stochastic Computing Element (SCE) capable of the operations +, -, ×, and ÷ has been designed and is being built. It can also commute the inputs, i.e., form B-A instead of A-B. The magnitude of the variables is mapped onto a 0 to 1 range while the sign is contained by a logical "0" for plus and a logical "1" for minus. In this representation algebraic summation of numbers requires a great deal of steering logic. However, it does lend itself readily to the operation of division, which was an important factor in its choice.

In the general logical design of the SCE each operation is designed around a fixed format which consists of a clocked output flip-flop P, and an up-down counter where required.

1.3.5 Details of Operations and Circuits

The circuits required for each of the algebraic operations are described below.

Addition:

In this circuit the output literally was forced to produce as many pulses as the sum of the inputs, through an OR-gate. Whenever an A and a B pulse coincided, this was detected by an AND gate and an UP-DOWN counter was advanced by one. When neither input had a pulse while the UP-DOWN counter did not indicate zero (i.e., it was storing a previously coincident pulse) an output pulse was produced while the UP-DOWN counter was reduced by one (Figure 4).

Subtraction:

To subtract B from A, a pulse was deleted from A for every pulse of B. The UP-DOWN counter is used to keep track of short period statistical variations when B may be larger than A.

If B actually is larger than A, the counter eventually will overflow. This is then used to switch the roles of A and B and to change the sign of the output. (Figure 5).

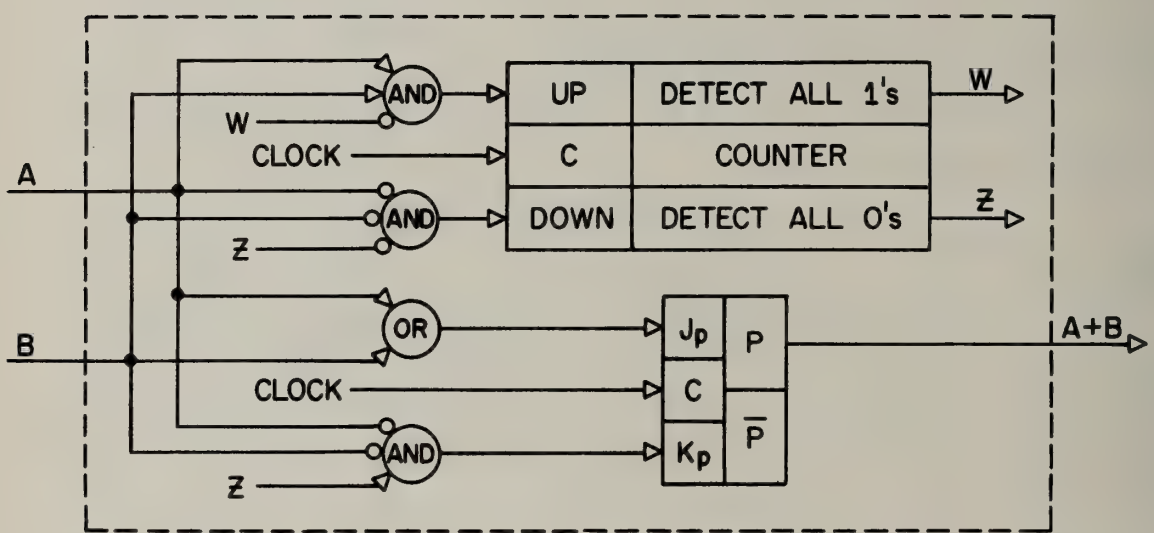


Figure 4. Addition of CRPS's A and B.

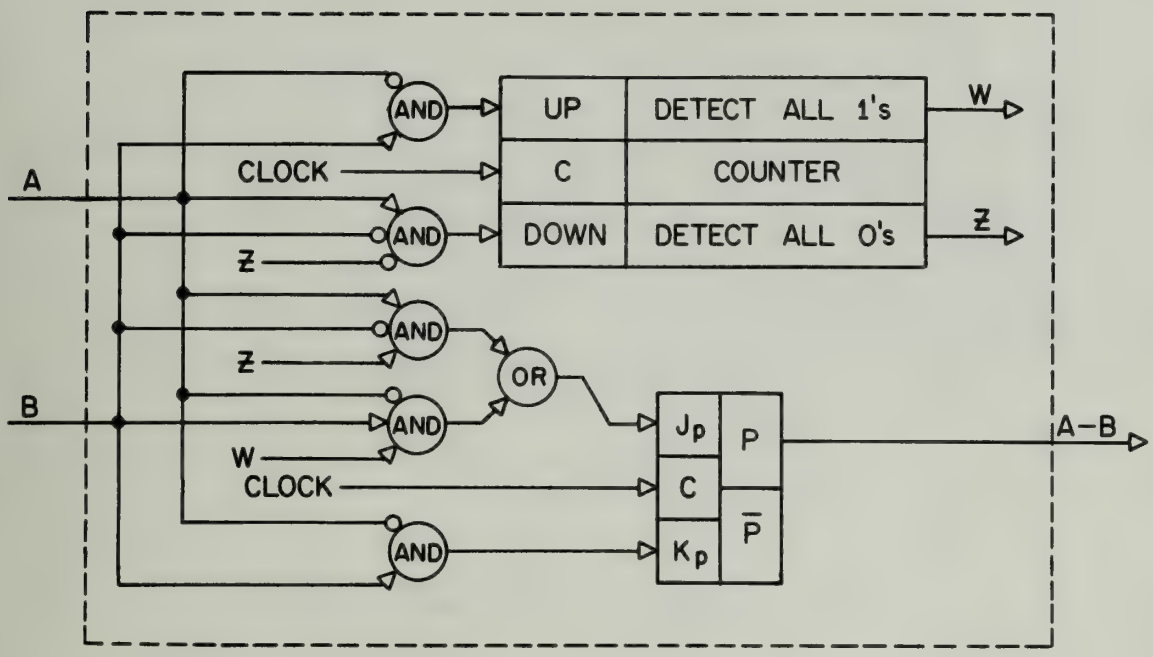


Figure 5. Subtraction of CRPS's B from CRPS A.

Multiplication:

Since numbers are being represented as probabilities the product is simply the combined probability of both inputs being "1". The simple AND-gate adequately fulfills this function. (Figure 6).

Division:

This has been discussed in Section 1.3.4 of this Report.

Squaring:

For squaring A, it has to be multiplied by A', where A' has the same probability as A but has a time independent sequence. The A' sequence is found by delaying A for one clock period. (Figure 7).

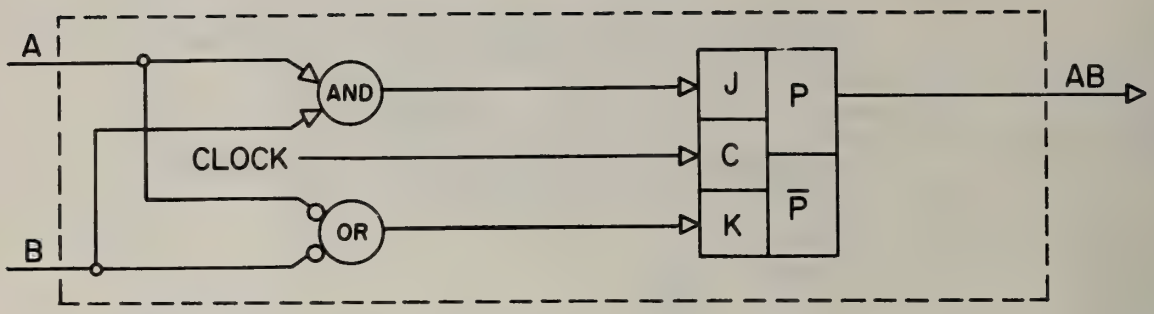


Figure 6. Multiplication of CRPS's A and B.

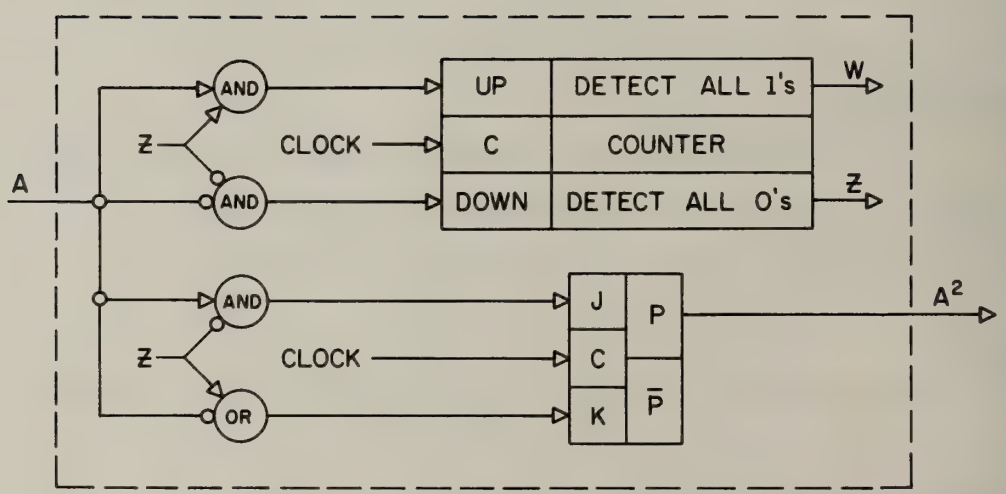


Figure 7. Squaring CRPS A.

Passing Input to Output:

Here a simple gate is used to gate input to output (Figure 8).

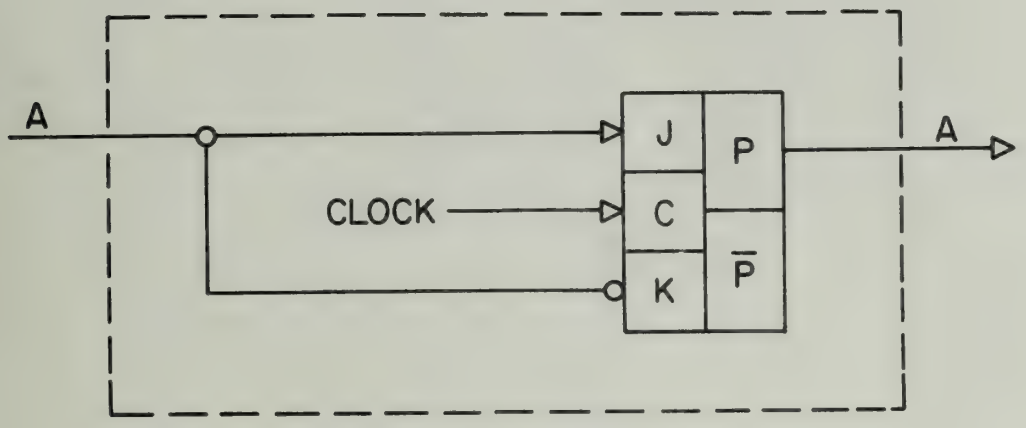


Figure 8. Passing CRPS A to the Output.

The complete SCE contains the following sub-units: gating to decode the operator code; gating to form the total expression for the output flip flop; UP-DOWN counter; sign determination circuitry.

The total number of wires to the outside world for each element is two for each operand, two for the output number, four for the operator, one for the clock, one CRPS connection for the scaling factor of 0.1, plus two for power, which gives a total of fourteen.

Conceivably if I.C. manufacturers could get the required circuitry on one chip, one could house the entire element in one package. Symbolically, such an element could then be represented as shown in Figure 9.

John Esch

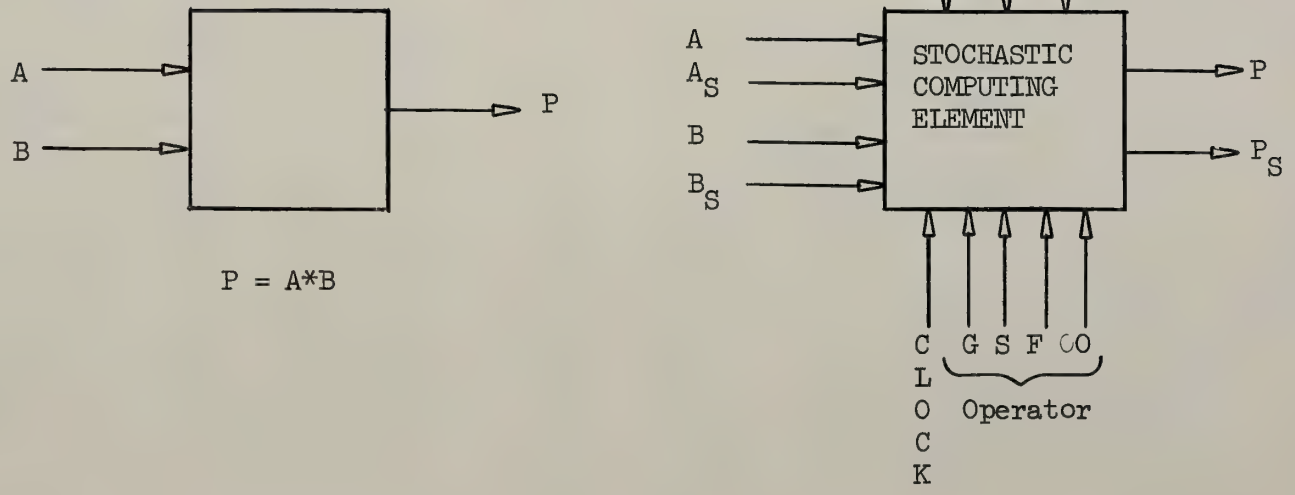


Figure 9. Stochastic Computing Element.

1.4 Phastor (Project No. 06)

The PHASTOR-project is nearing completion. A change from the original circuit has been made in that the ramp generator is now being driven by a modulo 125 counter. This counter uses three T.I. SN7470 I.C. Mod. 5 counters in cascade and is synchronized to a crystal controlled master clock. This clock also delivers the synchronizing pulse for the storage monostable. With this system stable storage has been obtained for a maximum of ten minutes. A schematic of the counter is shown in Figure 1.

A scheme to accommodate four storage cells has been devised and built, adding two extra gates to the monostable.

The addressing consists of a "WRITE" push button and flip-flop for each storage cell. In the normal switch position the flip-flop allows the storage cell to retain whatever information it is storing, while blocking any new input signal. When the 'write' button is depressed, both the 'write' and 'regen.' gates are opened, allowing the monostable to be stopped and then started at the appropriate moment.

The read out circuit uses a single sample and hold circuit, capable of being gated to any one of the four cells.

A moving coil $\pm$ 1% D.C. voltmeter is used as the indicating device. The whole system is battery operated and will be housed in a 16" x 12" x 6" case.

Larry Wallman

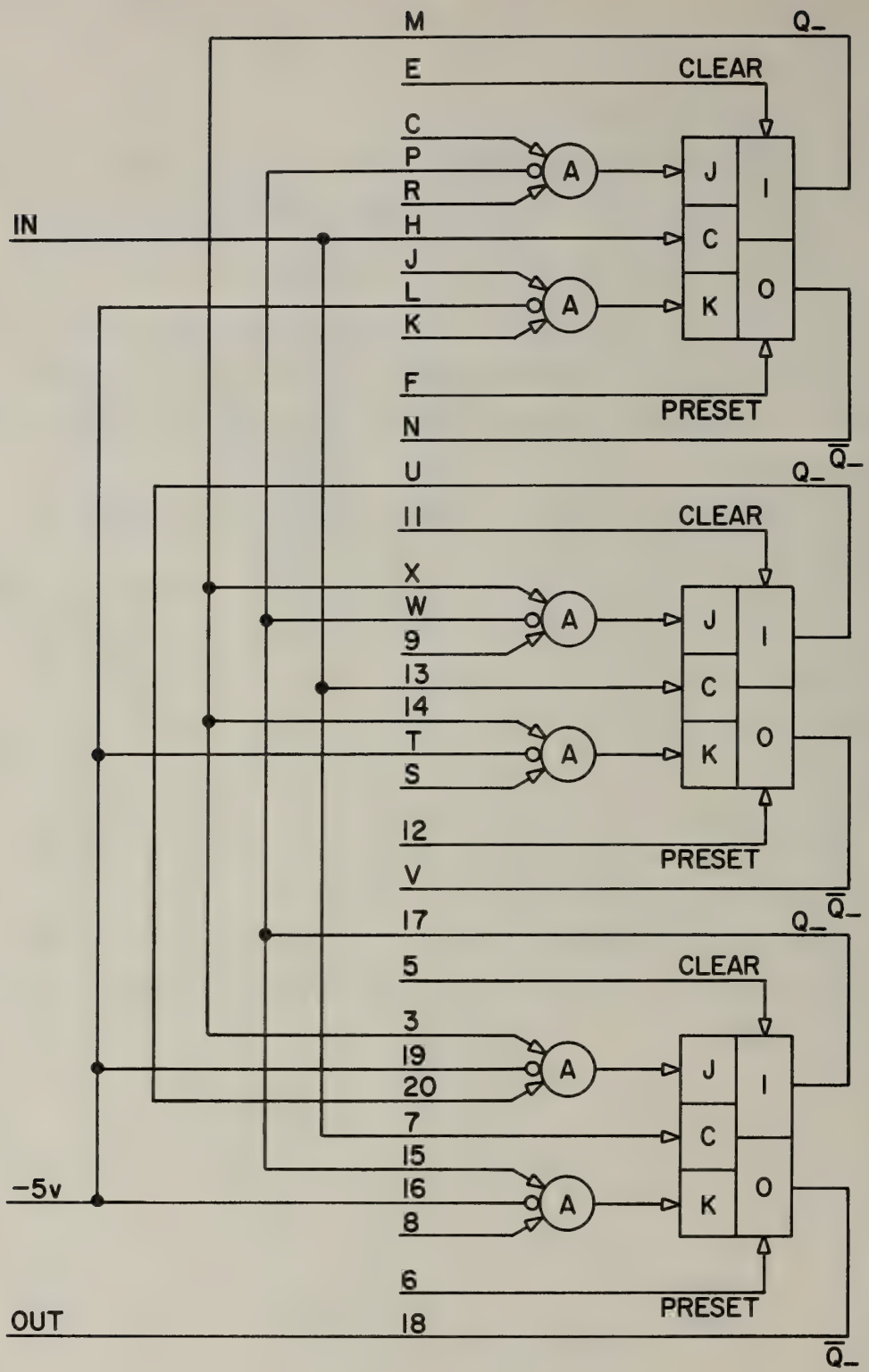


Figure 1. Modulo Five Counter.

1.5 Geomatrix (Project No. 08)

1.5.1 Geomatrix II

Geomatrix II uses a resistive grid and a switching system to control the node voltage of a number of chosen points in the grid. The voltages at all other points in the grid are determined by the currents that flow in the grid resistors. If the resistive grid is considered to be an infinite conducting plane, the voltages at all points may be determined by Laplace's equation with the controlled (fixed) voltages as boundary conditions. The voltages in the plane lie on equipotential lines determined by the boundary conditions. Straight lines, circles, ellipses, and parabolas are only a few possible shapes.

1.5.2 The Geomatrix II System

The system (Figure 1) contains the resistive grid and two circuits behind each grid point. One circuit is a WRITE circuit which has the effect of fixing the voltage of its grid point at one of the two boundary value voltages or allowing its grid point to float electrically. The WRITE circuit is controlled by a stylus which is discussed later. The second circuit behind each grid point is a READ circuit which has the effect of lighting a lamp at its grid point only if its grid point voltage is zero.

It is assumed that $B_1 \geq 0$ and $B_2 \leq 0$ so that in the grid B_1, B_2, or some line in between will always be at zero potential. The position of the variable resistor determines which line is at zero and thus which line is indicated by lighted lamps.

1.5.3 WRITE Circuit

The WRITE circuits have the function of fixing each of any chosen grid points at one of two given boundary value voltages. These circuits serve also as the input storage since all input information must appear as analog voltages on the lines corresponding to boundary conditions.

Such a circuit is shown in Figure 2 and has three mutually exclusive stable outputs: B_1 or B_2 ($1.5\ V \leq |\ B_{1,2}\ | \leq 5V$) or floating. The state of the WRITE circuit is determined by a pulse at the input in the following way.

Input pulse

+8V	writes B_1
-8V	writes B_2
+1.5V	erases B_2
-1.5V	erases B_1

The circuit has an inherent interlock so that it can never be in two states at the same time and in the off state draws negligible power. In either one of the on states the output impedance is quite low (a few ohms). The input R is a master reset for all WRITE circuits, thereby clearing the entire panel.

A novel, but simple, input mechanism is possible with the WRITE circuits. This is a panel (which could be the same panel containing the lamps) which has on its surface conducting islands corresponding to the node points in the resistive grid. Each conducting island is connected to the input of the corresponding WRITE circuit. With this setup, an operator using a conducting stylus connected to the proper voltages could "write in" boundary conditions with pencil-like motions. Erasures and corrections would also be permitted.

1.5.4 READ Circuit

The READ circuit has the function of lighting its lamp when its input is 0 volts. Such a circuit is shown in Figure 3. It uses only one transistor (T1) to produce both inverted (V_2) and non-inverted (V_1) signals. Signals V_2 and V_1 are put through an OR gate which produces

max (V_2, V_1) = V_3. At the lower limit of V_3, the voltage is just low enough to allow T_2 to turn on and light the lamp. The READ circuit has an input sensitivity of $\pm$0.15 volt and draws 20μA (for V_{in} = 0).

Bill Steiner.

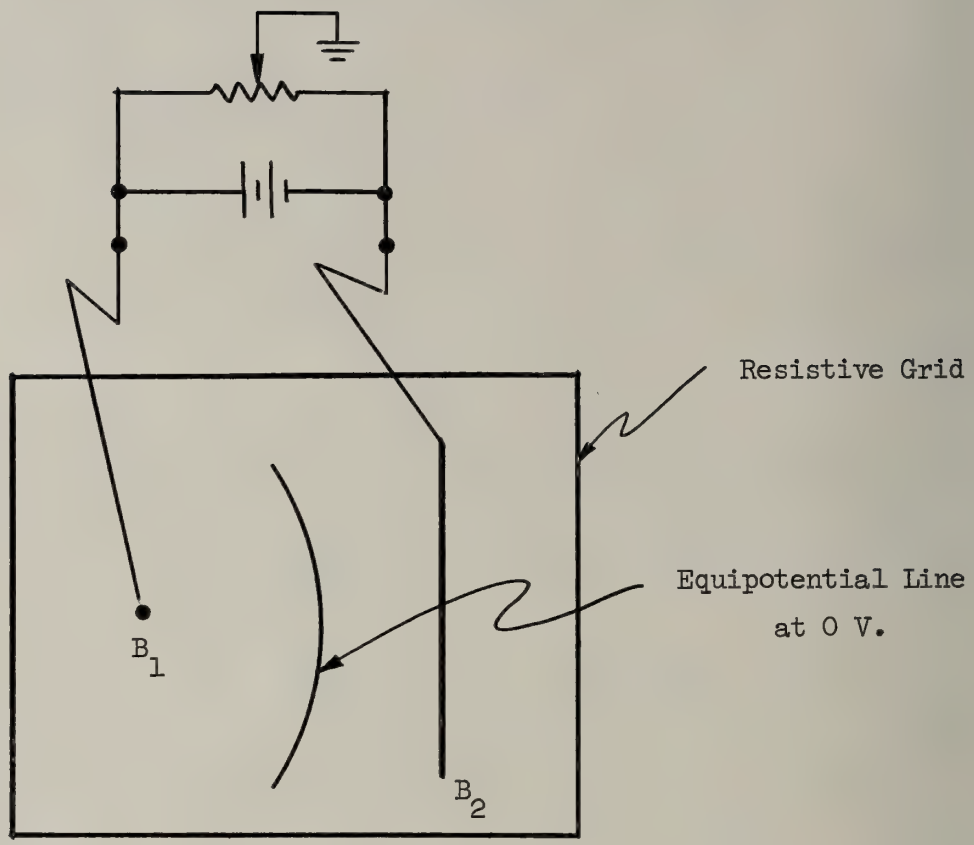


Figure 1. Geomatrix II System.

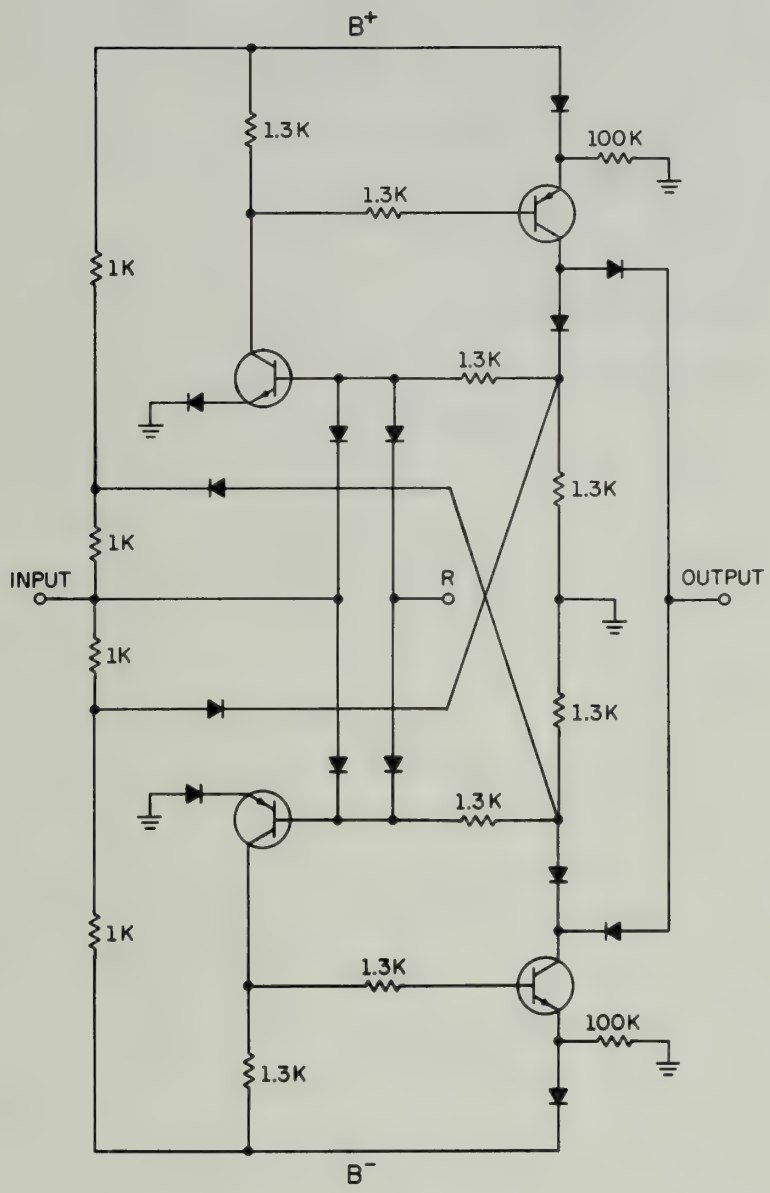
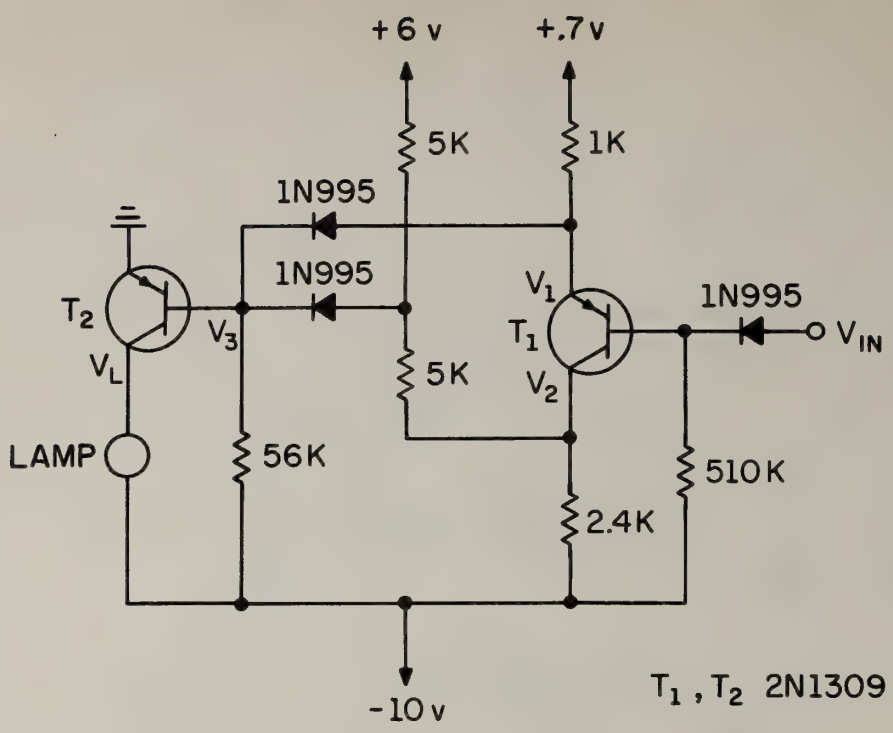


Figure 2. Write Circuit.



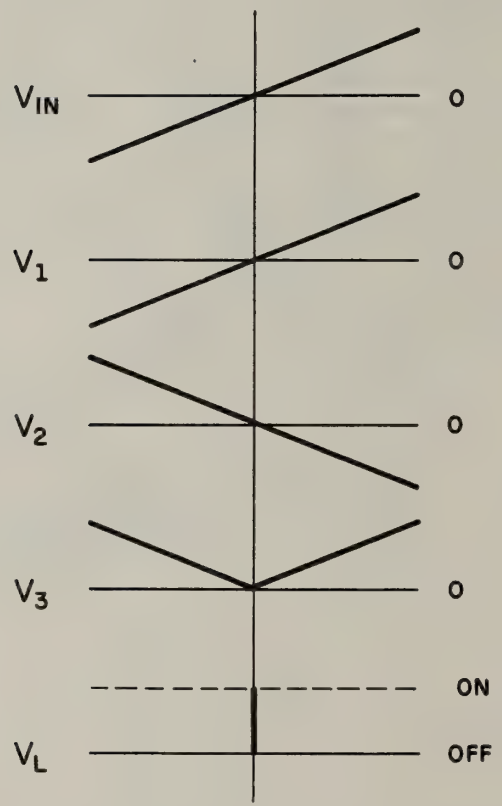


Figure 3. Read Circuit.

1.6 Mathematical Analysis of Computer Graphics.

This investigation aims at representing graphical displays by real continuous functions which can be used to reconstruct a close resemblance to the original display. The reconstruction is to be acheived by some encoding procedure. Most probably the coefficients of the functions describing the display will be transmitted.

Several types of polynomials are being investigated to find how they succeed, with a minimum number of terms, in describing outlines of various simple displays. Presently, both Least squares and Chebyshev polynomial curve fitting are being investigated.

Coupled to the problem of finding an appropriate function to describe a display, is the practical problem of how to break down a display into simple curves. This bears directly on the method of scanning to be employed and this problem is being considered together with those listed above.

Michael Payne

2. HARDWARE SYSTEMS RESEARCH

(Supported in part by the Atomic Energy Commission under Contract No. AT(11-1)-1469).

Summary

David Casasent's report deals with simulation studies in the OLFT system. The name, Delta Method, will no longer appear in these pages; this bandwidth compression project, of David Rollenhagen's, has been so completely modified as to warrant a new title. He gives a preliminary description under the heading of the Variable Interlace Scheme. In the area of Functional Encoding---another approach to bandwidth compression---the detailed transmitter design is given by Peter Oberbeck, while Art Simons discusses two possible implementations of a fast A/D converter. The final report, on the Tricolor Cartograph, is of an interim nature by Bill Kubitz.

2.1 OLFT (Project No. 12)

2.1.1 Simulation Studies

Work has continued with a simulation scheme for the system that will eventually be used to generate and modify Fourier Transforms of video on line. Final experiments can only begin at such time as the KDP chamber arrives, a date that has been regrettably delayed by administrative problems.

The aim is to be able to filter periodic, or quasi-periodic noise, from video signals, this noise manifesting itself in the form of striations on a TV-type picture. Figure 1 shows the placement of the relevant apparatus in the simulation scheme. Coherent, monochromatic (laser) light is broadened by a collimator and illuminates normally an object picture. Lenses L1 and L2 form a Fourier Transform (of desired size) of this picture and a spatial filter is located in the Transform plane. Lenses L3 and L4 are used to reconstruct an image (of desired size) from the filtered Fourier Transform, and this is projected on a monitor. The remaining equipment in Figure 1 serves to render details in the Fourier Transform more visible.

2.1.2 Beam Shutter

It was originally thought that it would be possible effectively to desensitize the active surface of the Fourier Transform pickup camera during the time that the video picture is being written on the KDP crystal. It now appears that this cannot be done with either a vidicon or image orthicon tube. Consequently, it will be necessary to use a beam shutter in the incident light path. This device makes use of the transverse electro-optic effect and requires only a 300 volt signal to operate it.

David Casasent

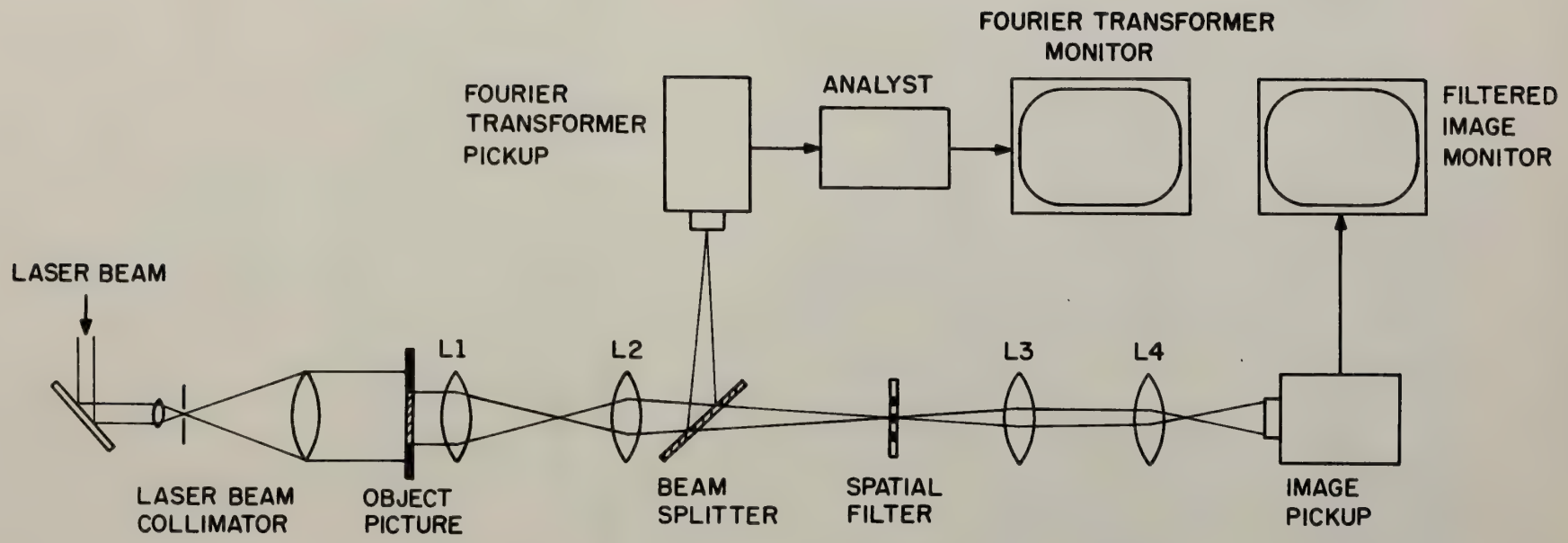


Figure 1. OLFT Simulation Scheme

2.2 Bandwidth Compression by Variable Interlace (Project No. 14)

2.2.1 Introduction

The variable interlace scheme that will be described below is a development of what was formerly called the delta method. Certain aspects of the delta method have been sufficiently changed to warrant a new name for the project, even though the variable interlace scheme retains the central idea of its predecessor, namely, that of detecting differences between successive television frames and using the amount of difference to control the bandwidth of the transmitted signal.

2.2.2 Variable Interlace

An arbitrary interlace scheme can be thought of as one with n fields per frame; in a given field every nth line is scanned, starting at some reference line which itself is changed from field to field so that all lines are scanned within one frame. If the field time, rather than the frame time, is fixed, then it is evident that the transmission bandwidth is inversely proportional to n, provided that the line frequency is appropriately scaled.

The basic feature of the present scheme is that n is allowed to vary, its value being determined by the amount of information that changes between successive TV frames. For given n, it is important that the first scan line in each field is so chosen as not to produce the visual effect at the receiver of drifting horizontal bars. The scan sequence that has been adopted to achieve this is shown in Table 1. (The symbol $\lceil x \rceil$ means "the largest integer not greater than x".)

Field No. \ Scan No.	1	2	3	4		n
1	n	1	n-1	2		$[(n+1)/2]$
2	2n	n+1	2n-1	n+2		$[(3n+1)/2]$
3	3n	2n+1	3n-1	2n+2		$[(5n+1)/2]$
4	4n	3n+1	4n-1	3n+2		$[(7n+1)/2]$

Table 1. Variable Interlace Scan Sequence.

2.2.3 Status

The system design is nearly complete. It is hybrid in nature, but contains a considerable amount of digital circuitry. Much time was spent in designing a general purpose analog gate for use in both this project and others. Final tests on this circuit will be reported on subsequently.

David Rollenhagen

2.3 Functional Encoding (Project No. 15)

2.3.1 Description of Transmitter

A complete diagram of the transmitter is shown in Figure 1. It is designed to encode the video from a line drawing. A typical line of video is shown in Figure 2.

Each of the discontinuities in the video corresponds to a black dot or part of a line on the screen. This video is then converted to standard logic levels as shown in Figure 3.

The converted video signal sequentially gates a clock into a series of 32 counters (Figure 4) by a 32 bit shift register (Figure 5A, 5B). Thus, the contents of the counters represent the elapsed times t_1, t_2, t_3, ..., t_{32}, between successive video pulses. These are gated, during horizontal blanking, into a series of 32 9-bit registers (Figure 6), allowing the counters to be cleared before possible refill on the next sweep. Meanwhile the contents of the registers are gated sequentially at a rate determined by the bandwidth selector (Figure 7), into a D/A converter, with the aid of a 32 input NAND (Figure 8) gate. Because the bandwidth selector gates the contents of the registers at a rate less than that of the video gating the counters, a bandwidth reduction takes place. The output of the D/A converter is then a set of voltage levels proportional to the time intervals t_1, t_2, ..., t_{32} and of a duration determined by the bandwidth selector (Figure 9). The master sync logic card (Figure 10) provides synchronization pulses during horizontal blanking to gate registers, clear counters, etc. Interconnection of these cards is shown in Figure 1.

Peter Oberbeck

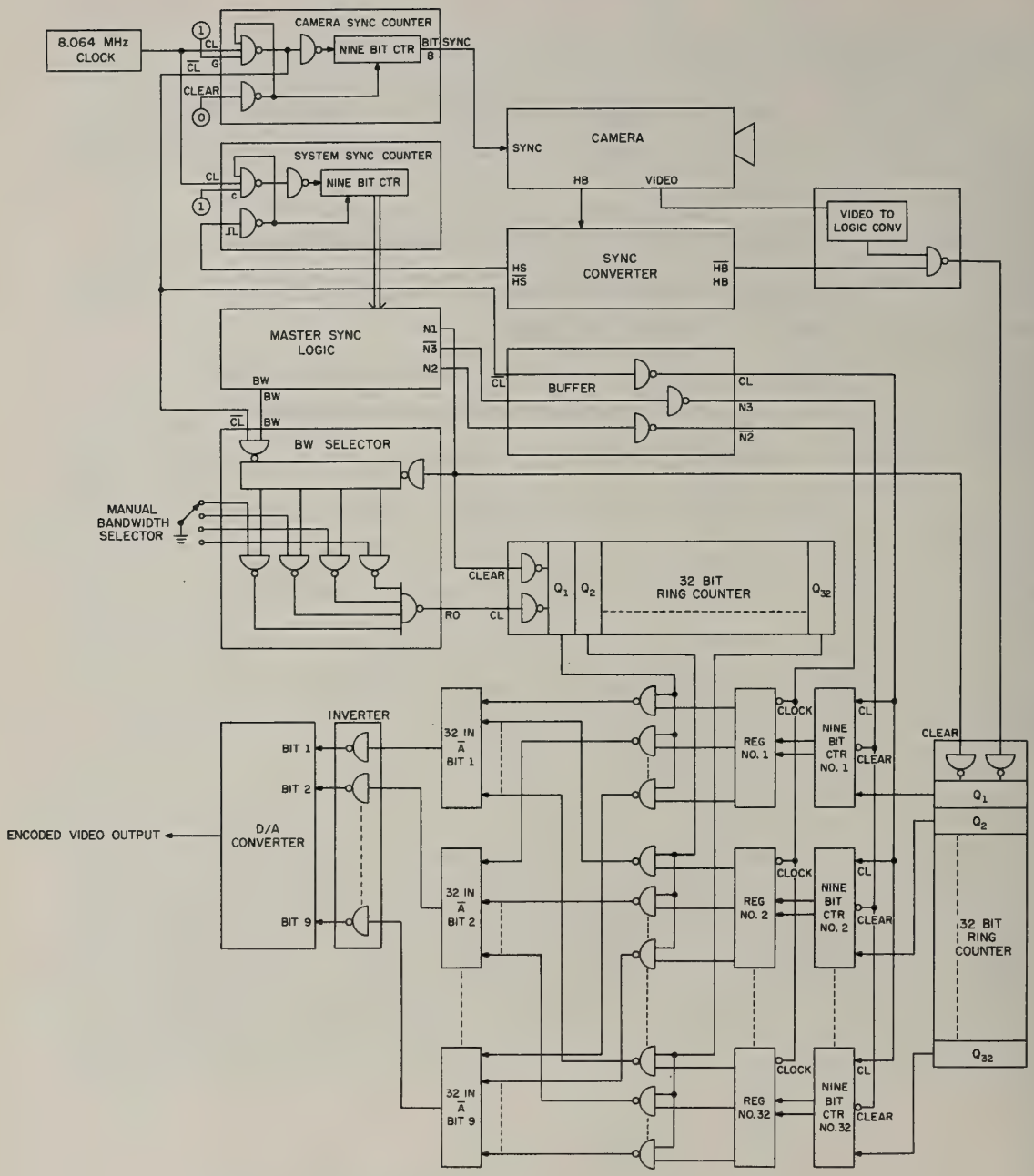


Figure 1. Transmitter Block Diagram.

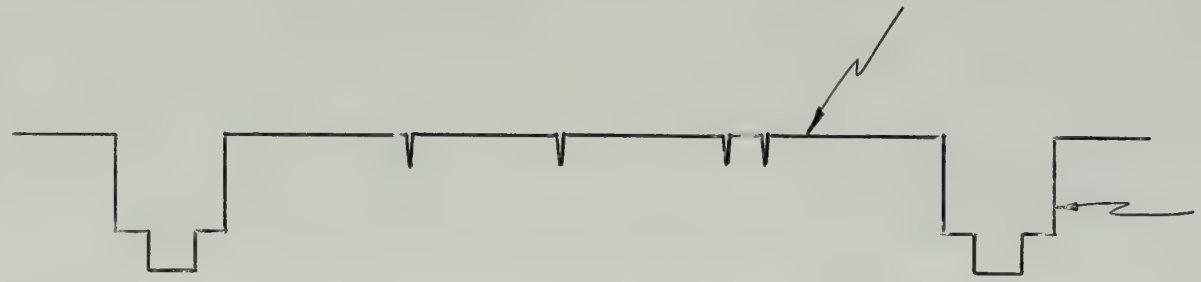
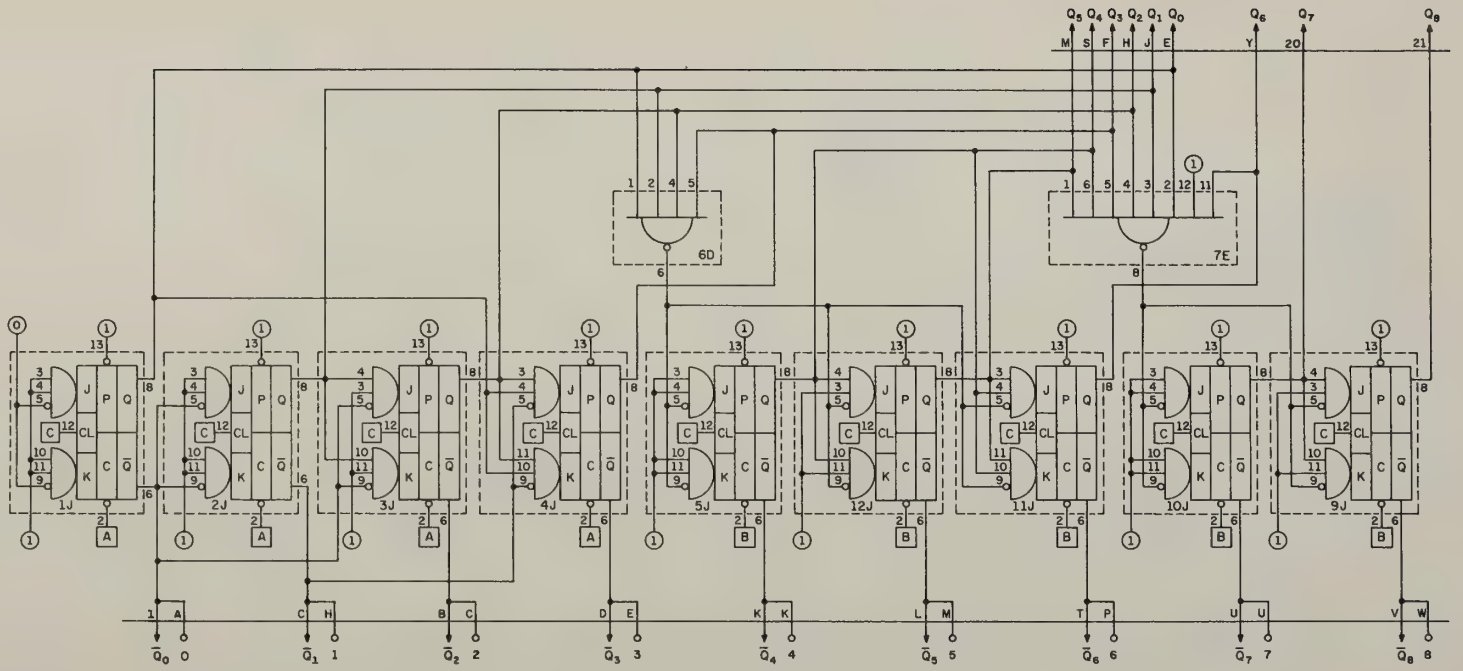
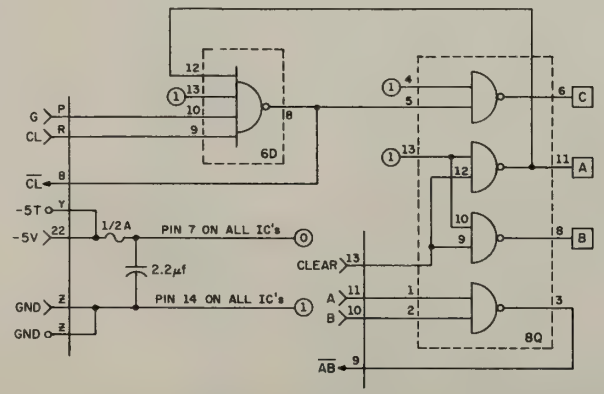


Figure 2. A Typical Line of Video.

Figure 3. Converted Video Signal.





PARTS LIST:

9	JK FLIP-FLOPS	SN7470N
1	8 INPUT NAND GATE	SN7430N
1	DUAL 4 INPUT NAND GATE	SN7420N
1	QUAD. 2 INPUT NAND GATE	SN7400N

Figure 4. Nine Bit Counter.

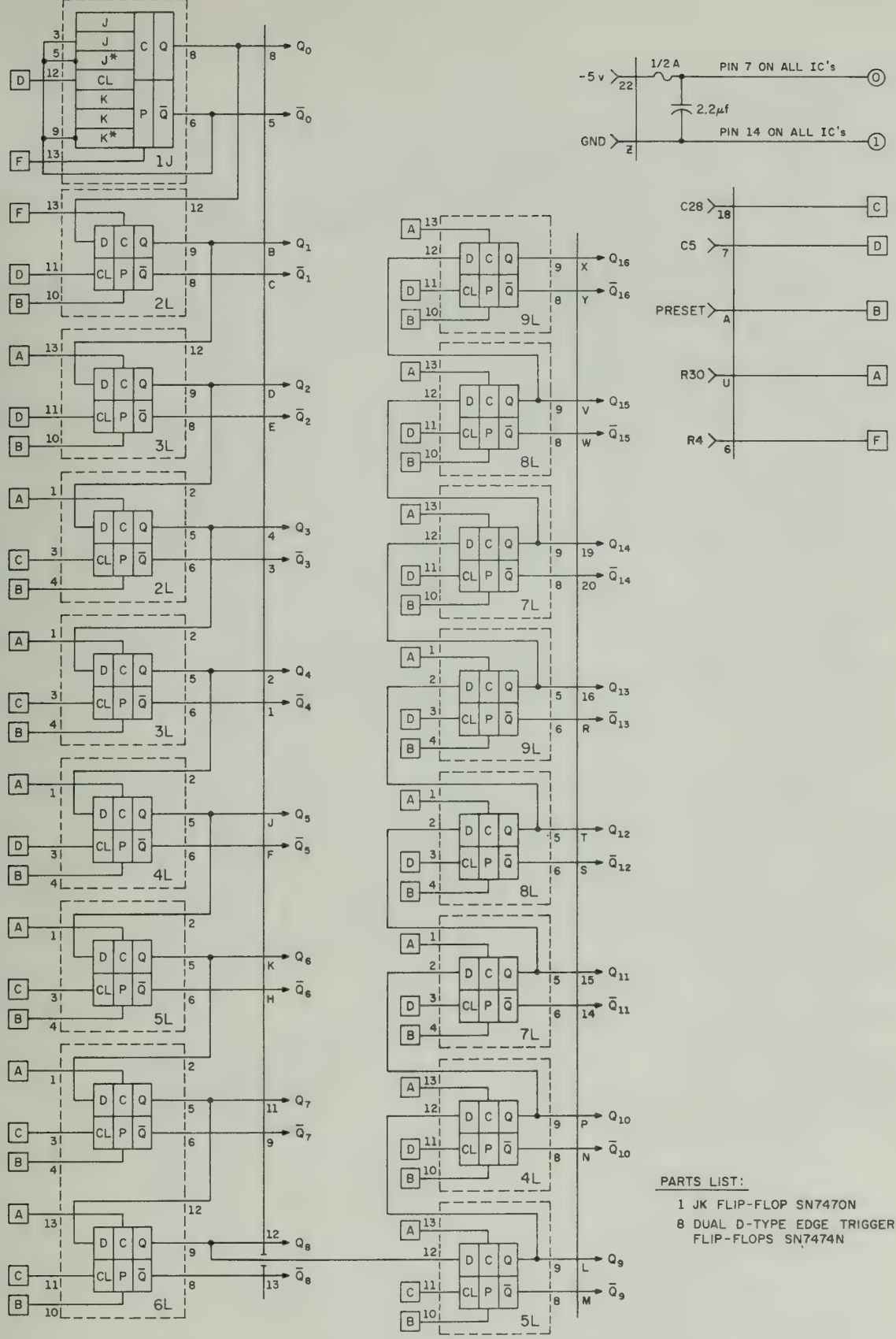


Figure 5a. 32 Bit Shift Register (Card I).

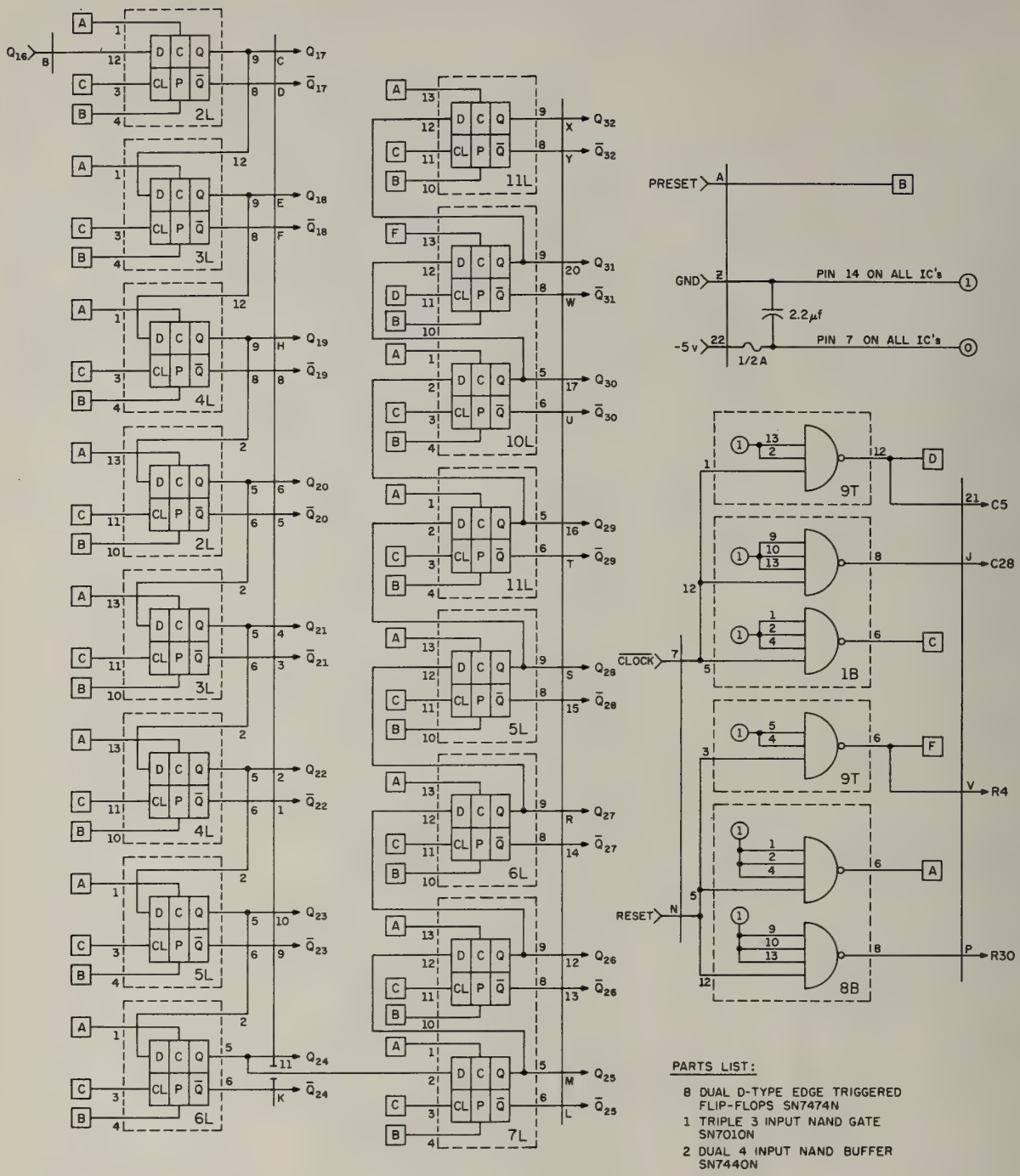


Figure 5b. 32 Bit Shift Register (Card II).

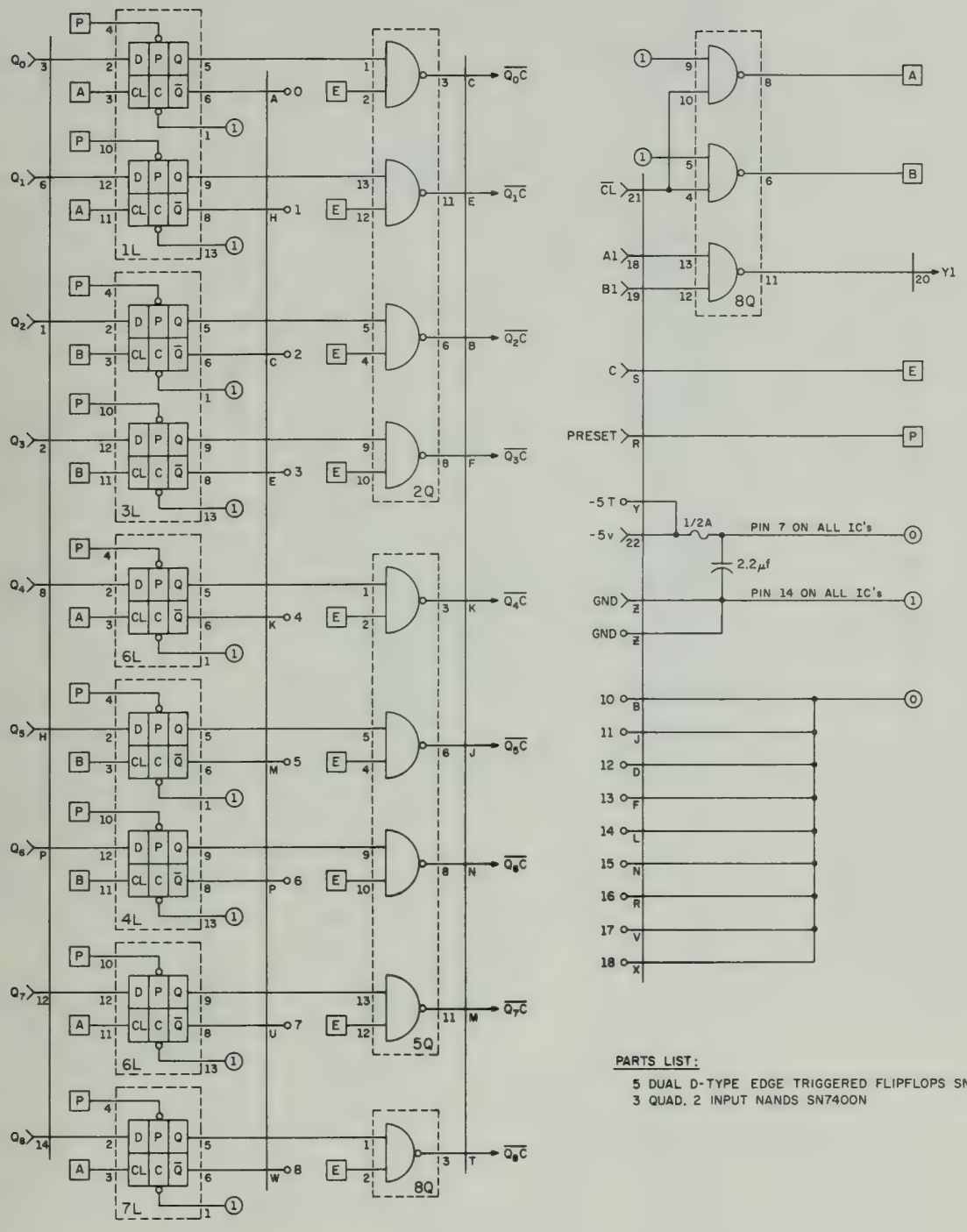
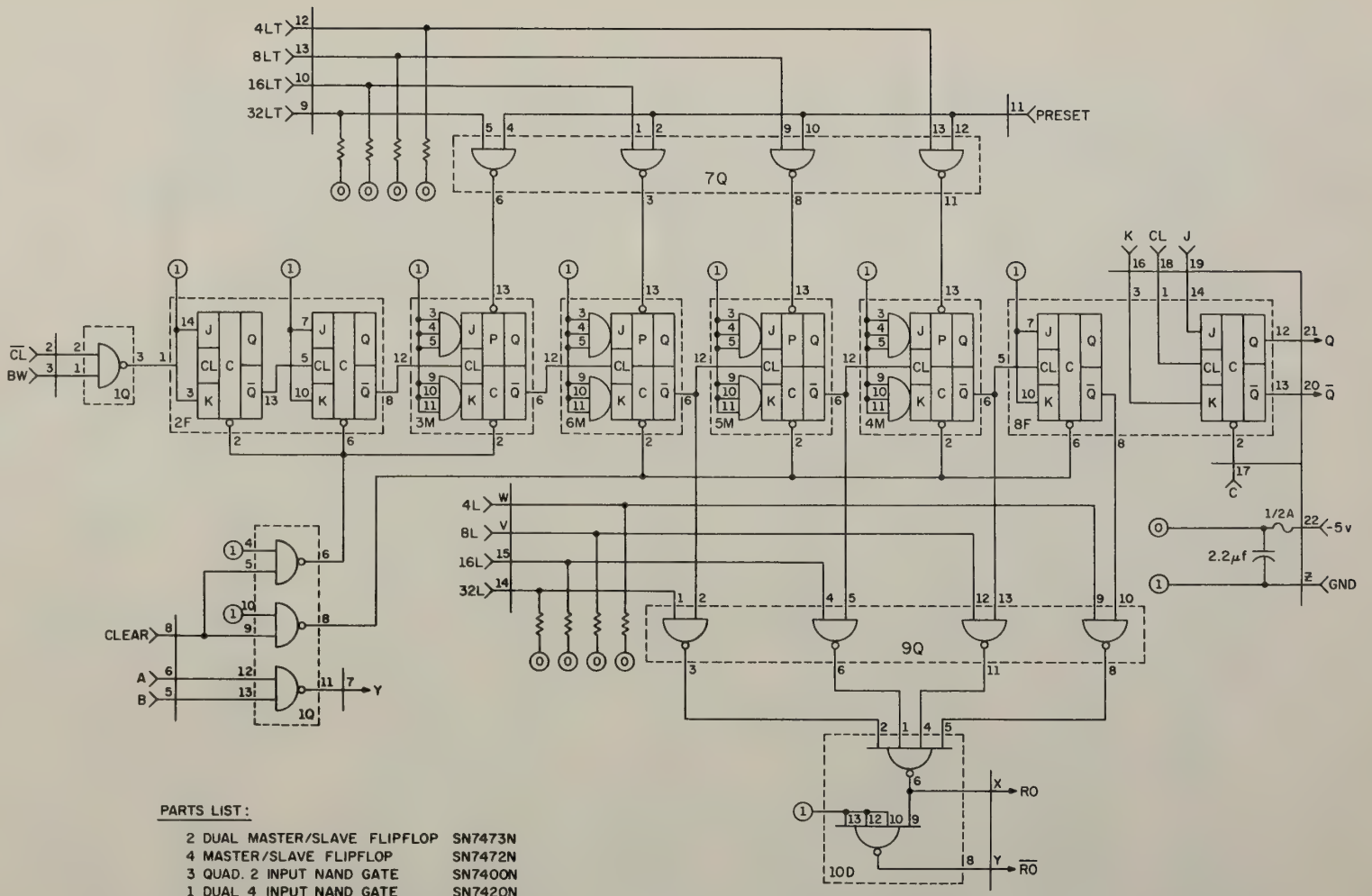


Figure 6. Nine Bit Register.



PARTS LIST:

2 DUAL MASTER/SLAVE FLIPFLOP	SN7473N
4 MASTER/SLAVE FLIPFLOP	SN7472N
3 QUAD. 2 INPUT NAND GATE	SN7400N
1 DUAL 4 INPUT NAND GATE	SN7420N
8 180 Ω 1/4 WATT 5% CARBON RESISTOR	

NOTE:

-5v TO PIN 7 OF ALL IC's EXCEPT PIN 11 OF SN7473N
GROUND TO PIN 14 OF ALL IC's EXCEPT PIN 4 OF SN7473N

Figure 7. Bandwidth Selector.

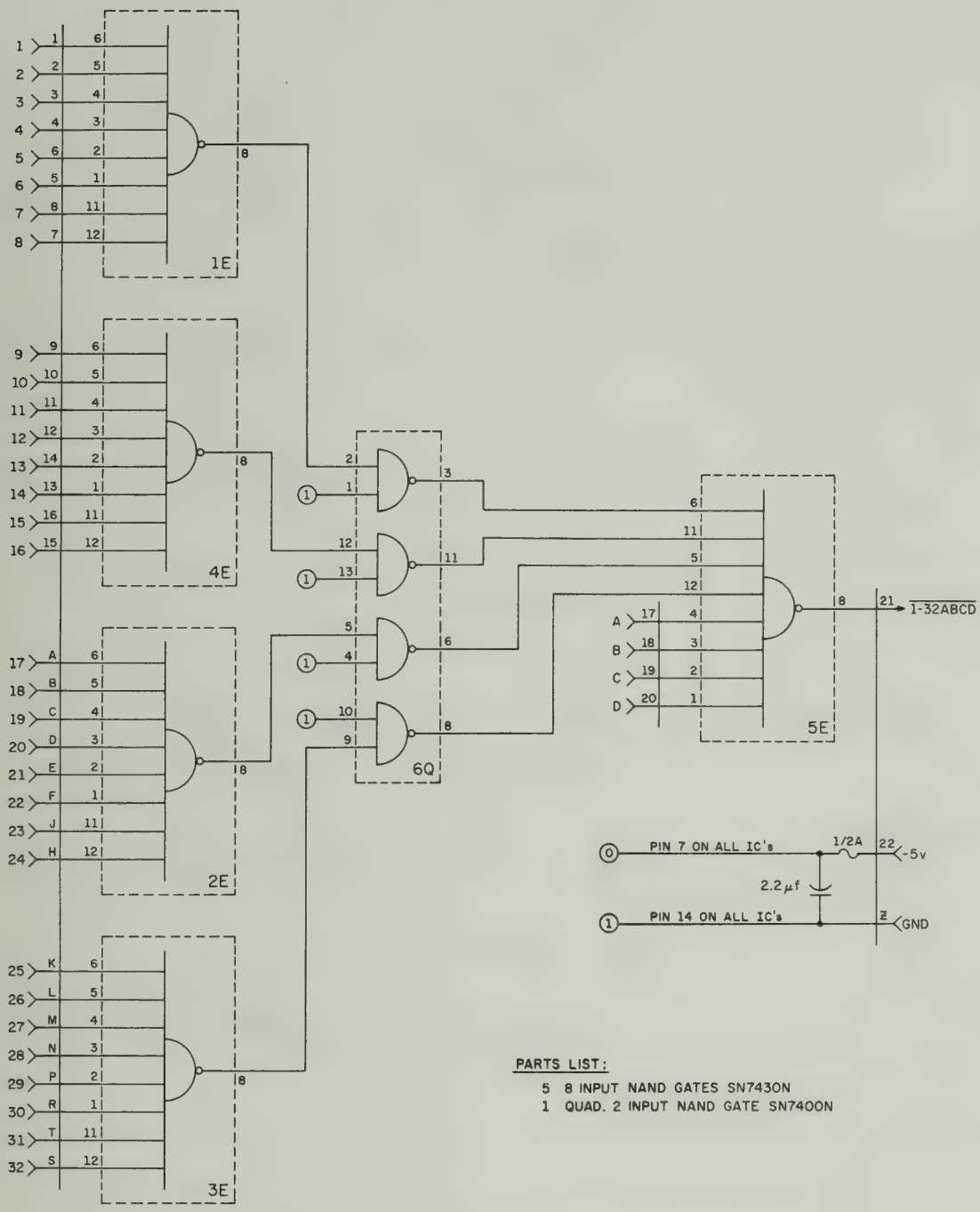


Figure 8. 32 Input NAND Gate.

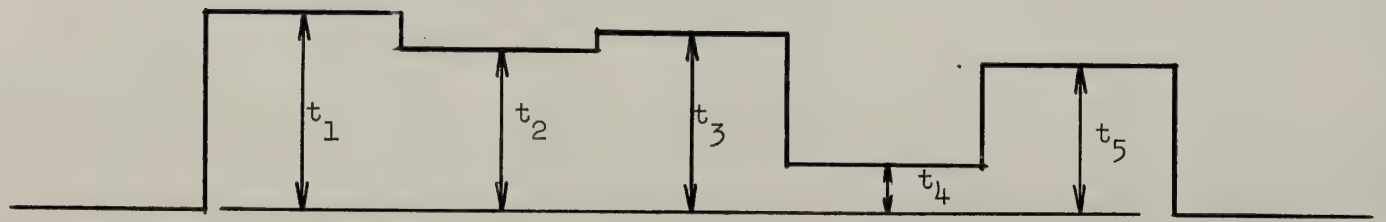


Figure 9. Encoded Video.

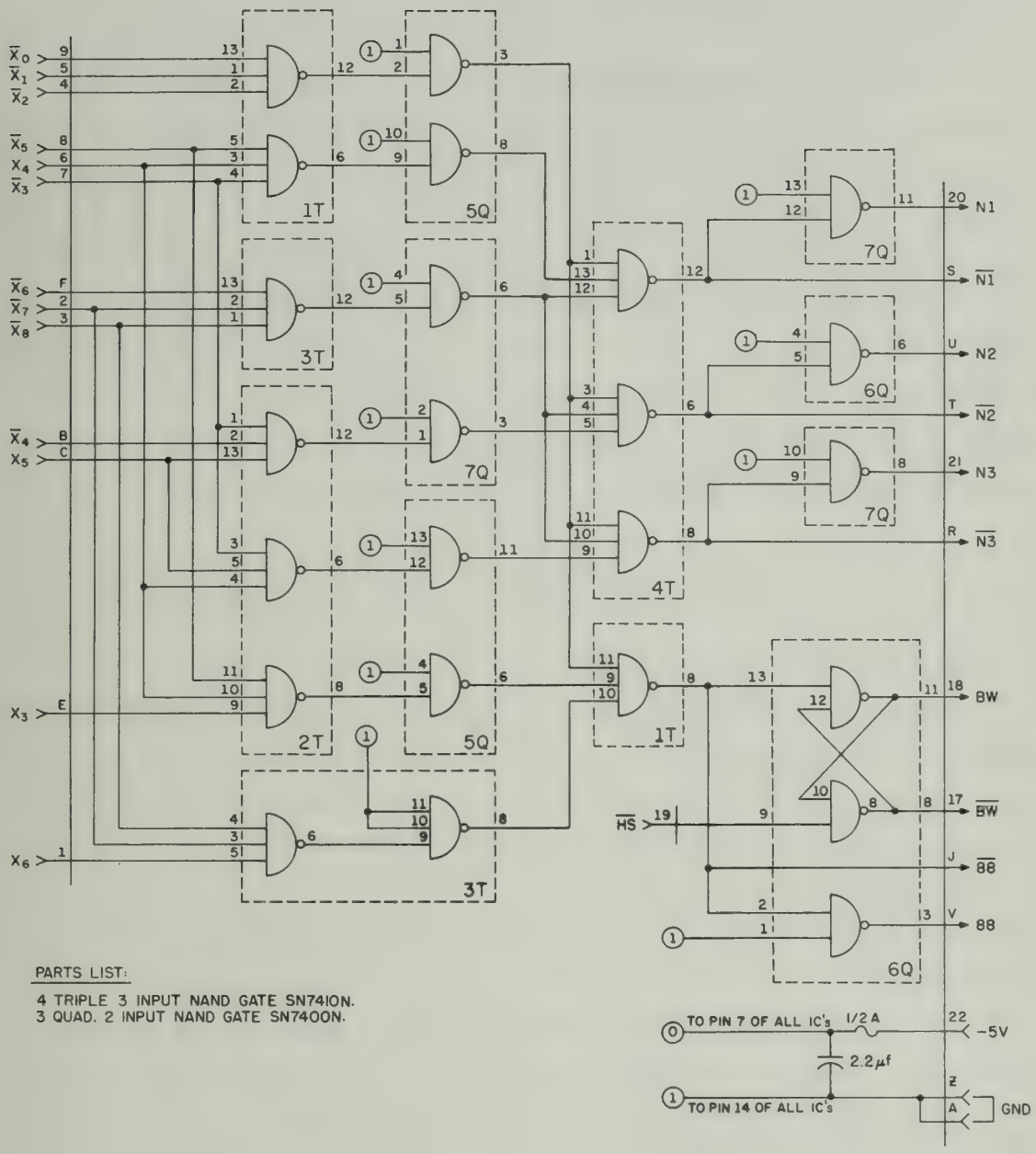


Figure 10. Master Synchronization Logic.

2.3.2 A/D Converter

As mentioned in a previous report, a 9-bit analog-digital converter capable of converting 9 bits in 1.6μsec must be built. Two designs are at present being investigated, the first of which is shown in Figure 11.

First, a comparison method is used to obtain the five most significant bits. The basis for this technique is a set of comparator circuits which compare the unknown voltage with a series of reference voltages. In general, to obtain N bits of information, 2^N-1 comparators are needed. Since the comparators work simultaneously, this method is extremely fast. For a system requiring a large number of bits, however, the comparison method requires so many comparators that it is no longer practical. It was decided to determine five bits with this method because the number of comparators is still reasonable (31 are needed), while allowing enough time to determine the remaining four bits.

The four least significant bits are determined by a count-down method. After the 31 digital outputs at the comparators are encoded into the five most significant bits, they are shifted into a 9-bit register with the four least significant bits set to zero. These 9 bits are then fed into a digital-analog converter, the output of which is compared with the original input signal. If they are equal, the process stops and the conversion is completed. However, if the input signal is larger than the D/A conversion of the five most significant bits, a clock is gated into the register until the output of the D/A converter does equal the input signal.

An alternative method has also been suggested, as shown in Figure 12. Here the five most significant bits are once again determined by a comparison method, but they are gated into a 5-bit register and then a 5-bit D/A converter. A 4-bit register representing the four least significant bits is again set to zero. If the output of the D/A converter equals the input signal, the process stops. If the input signal is larger than the output of the D/A converter, a clock

is gated into the 4-bit register. Simultaneously, a ramp voltage is triggered and added to the output of the D/A converter, and the sum of the two is compared to the input signal. When they are equal the clock is gated off and the output may be taken from the two registers.

The second method offers the advantage of requiring only one D/A conversion, while the first method requires a conversion every time a clock pulse enters the register. In the first method as many as 16 high speed conversions may be necessary. However, the second method does require additional circuitry, the ramp generator, and an operational amplifier. Presently, both schemes are being investigated.

Arthur Simons

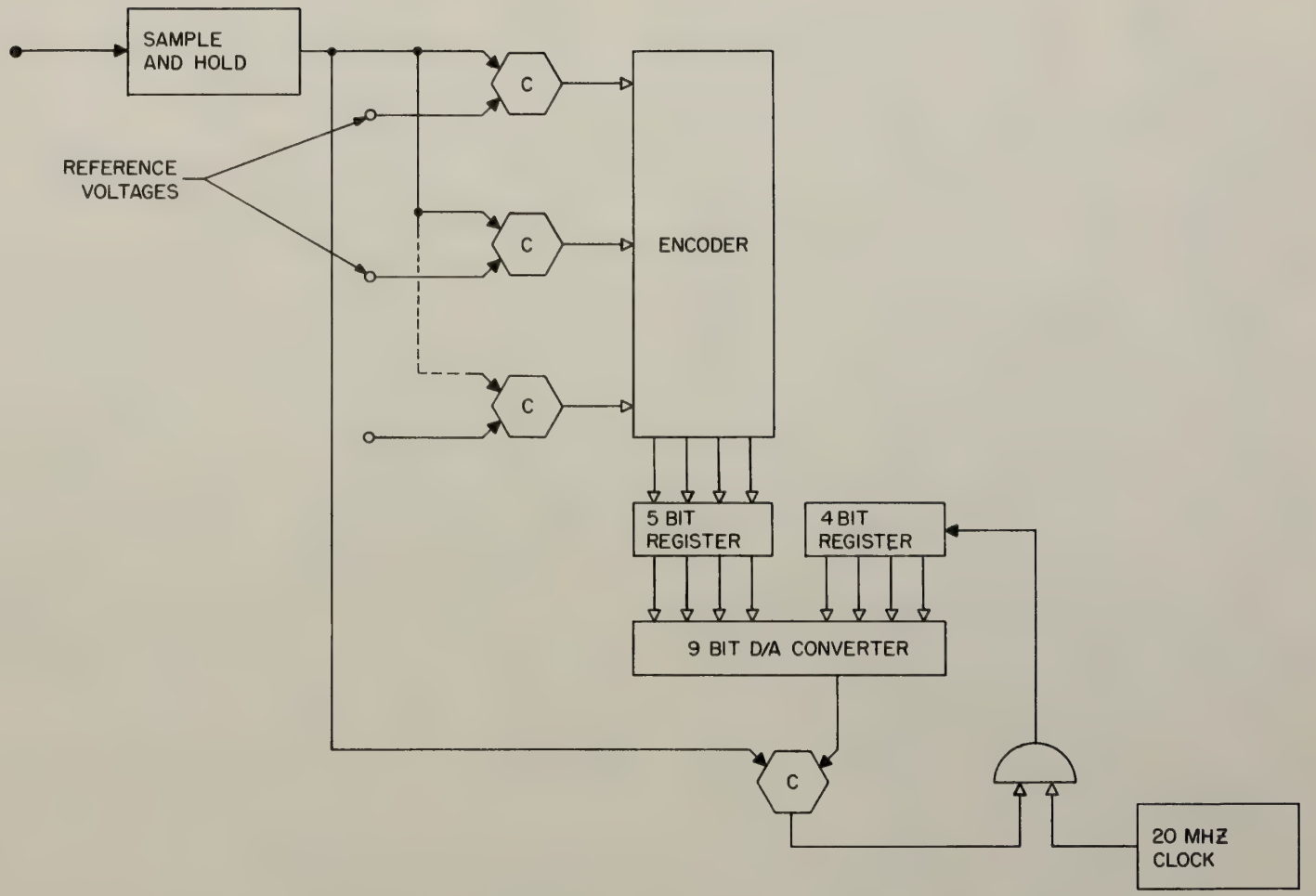


Figure 11. A/D Converter - Type I.

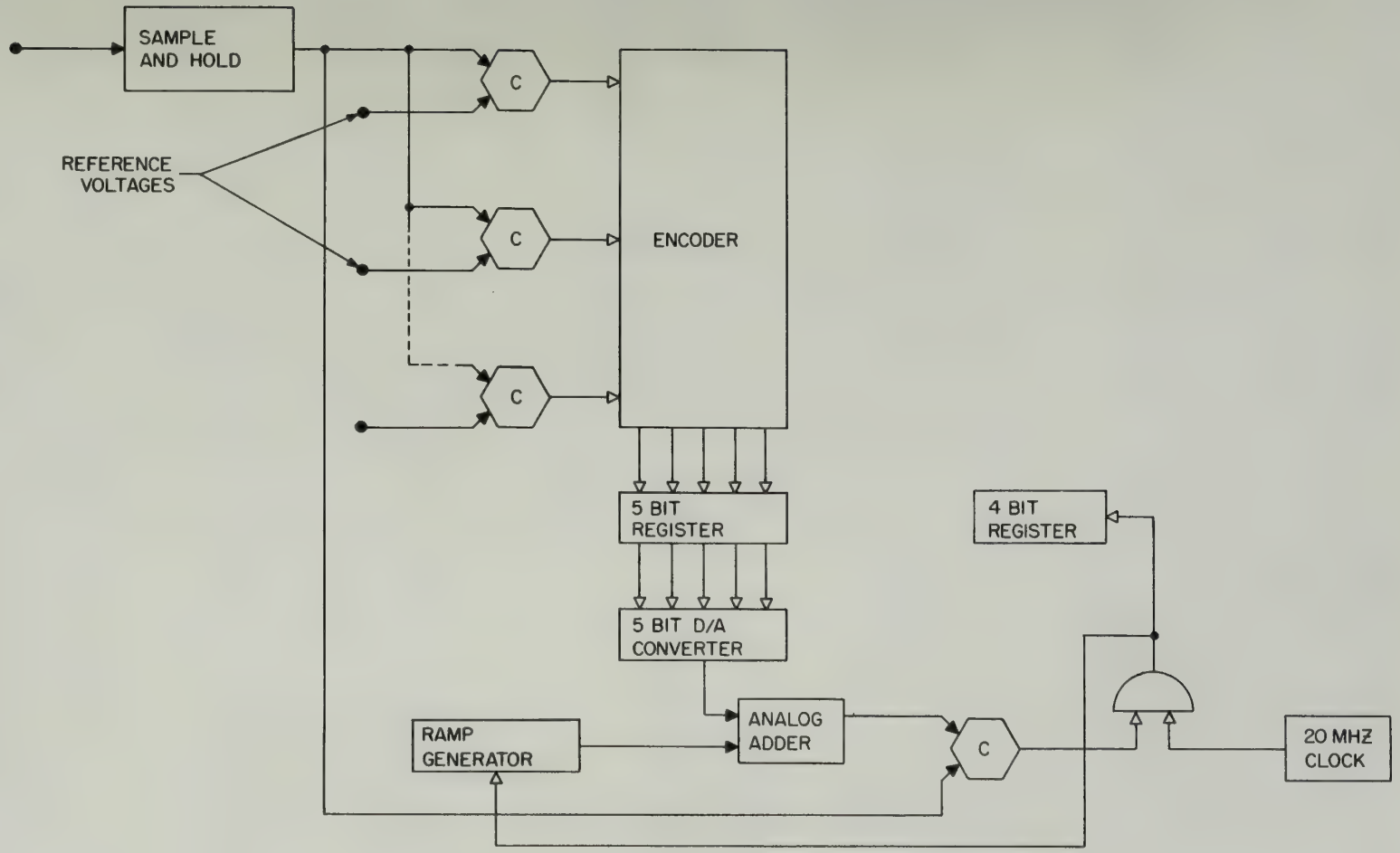


Figure 12. A/D Converter - Type II.

2.4 Automatic Tricolor Cartograph

The design of the cartograph has proceeded along lines described in the last Progress Report. Most of the hardware required has been received or is on order. The video disc memory is scheduled for delivery in September. Some circuit design still remains. It is expected that the system will be ready for testing in late September or early October. The next Report will explain the sequence of logical decisions used to accomplish the automatic coloring.

William Kubitz

(This work is supported in part by Contract No. AT(11-1)-1469 of the Atomic Energy Commission and in part by the University of Illinois.)

3.1 Boots Time-Sharing System

Check out of BOOTS-II was completed to the point that the system will be put into operation in the first week of May. Files were reorganized to make it possible to retain binary files only for checked out programs.

L. Greninger

With regard to the BOOTS system, three basic changes have been made. The input-output routine and line scanning routines have been rewritten. The results visible to the user are slight improvement in speed, implementation of non-printing characters in file names and ID's, and use of six character file names in the use of the RDØNLY command.

The main obstacle for current use of the time share system is the failure of the RUN command to correctly load the user's core load. The reason for this is not clear to myself or to Lars Greninger, who made the associated changes in the BOOTS system.

A. Whaley

3.2 TIPSY

In the realm of time sharing, TIPSY has been modified in all of its arithmetic sections, so that it will handle all of its standard functions with complex numbers.

Several new features are therefore available in this connection. The incorporation of an imaginary constant in an arithmetic assignment statement follows the basic form:

```
1 C = A + BI,
```

where C is any one letter variable (standard in TIPSY), and A and B are any numerical constants. Either the real or imaginary parts may be left out. In addition, these complex components may be combined with any normal TIPSY assignment statement, for example:

```
1 Z = LOGB(X + 3 - 2.7I)-5I,
```

where I is taken to mean the complex unit vector. The letter I may still be used as a normal variable. Printing of variables with complex components will be of the following form:

```
A =  +1.  IM =  .56000000E+02,
```

where A has the value 1 + 56i.

At the time of the modification, three errors were corrected--those that occur when a FOR controlled variable becomes zero, when (Exp) ** A is formed with EXP having the value zero and when the square root of a negative number is formed. To the user, it is unchanged for real operation. If an I is typed after a constant, it becomes complex, complex numbers are output as a real part followed by

```
'IM = NNNNNNNNNNN'
```

This is not printed if the imaginary part is zero. FOR loops only check the real part of the number.

A. Whaley

3.3 PDP-7 Program

The new PDP-7 SPU processor for BOOTS II was completed. The new programs include an expanded communication between the PDP-7 and BOOTS so as to more efficiently process users. The features of the new system include the following:

1. A login time limit of 2 minutes to prevent unauthorized users from tying up data-set lines. Unlike the old system, the timer is not reset by sending across characters.
2. A special command from BOOTS to tell the PDP-7 when BOOTS is flushing itself, allowing the PDP-7 to transfer itself into the TS OFF state. (Also a special command to tell when TS has been reloaded.)
3. An expanded user command set to allow users to input and output ASCII coded paper tape from their consoles.

4. A new operator command set to allow the following:

   a. Adding or deleting an addendum to the TS off message from the PDP-7.

   b. Sending a single line message to all users currently logged into BOOTS.

   c. Obtaining a log of all logical ports with their current physical port assignments and an indication of their current status in BOOTS (logged in or not).

5. A new command to reassign to any logical port a new physical port. (This is available from all consoles including the operators console.) Reassignment proceeds only after the user logs out, times out, or enters the TS off state.

A full description of the PDP-7 commands and how to use them will appear in the BOOTS II Manual.

A. Otis, Jr.

3.4 Loader

The time share sort merge program has been altered and corrected to fit into the current time share system. A programming memorandum is being prepared and will be distributed soon.

C. Ellis

3.5 Conversion Program

A tape conversion program was finished, allowing tapes loaded in the 7094-Havoc format to be used on ILLIAC II. The corresponding output conversion program has also been completed. The conversion program has been incorporated into the batch processor, allowing for simple operation of the two functions.

A. Whaley

3.6 System 360 Console Planning

Study has continued on the input phase of the 360 PL/I subset. A syntax analyzer is being written and some thought is being given to choose a useful intermediate language of a Polish post fix type. A key question is "should it contain names in symbolic form, or should they be table addresses?" Influencing factors are:

(1) Table addresses will speed the interpretation pass; without them, it is probably wise to do a second translation pass.

(2) Table addresses will shorten the Polish string, and make it easier to put it in a word organized structure.

(3) Table addresses are not possible if the syntax analysis is performed on a deficient machine (the PDP-7?).

(4) If table addresses are used, then that slot in the table must remain allocated as long as the program is in intermediate form. Since this would apply to all program files saved on the disk file, unless they were to be retranslated, the name table (which must be saved at all times) could be large.

(5) Table addresses make it difficult to know when to delete a variable from the table.

There appears to be three possibilities:

(a) Convert to symbolic Polish, use that as the saved form, and arrange for the interpreter to convert to a table address form immediately prior to execution.

(b) Save the source form only, and convert to table address form of Polish when a program is brought in from the disk file.

(c) Save the table address form, where each program has its own table. Linking from these to the master table would be necessary at interpretation time.

The latter would give the lowest overhead for initiating program interpretation, but the slowest interpretation time per statement. (b) would minimize disk space and give the greatest overhead.

C. W. Gear

3.7 Declarative Statements

A detailed flow chart for syntax checking DECLARE statements in PL-I and producing a form of intermediate language which can easily be converted into table entries has been almost completed.

Each identifier names in a DECLARE statement causes a string of 12 bytes (8 bits each) with the following format to be generated:

BYTE

0-5 Characters of the identifier (1 per byte: maximum of 6)

6-8 Attribute information

9-10 Further information pointer (for array, DEFINED, INITIAL, LABEL and BIT attributes)

11 All zero except for an identifier which has been declared an ENTRY with parameters.

Bytes 6-8 are a bit significance table; when an attribute specified for the given identifier is recognized, the table is checked to see if the attribute is allowed in combination with those previously specified. If so, the bit indicating the given attribute has been specified in set to 1. Bytes 9-10 contain a pointer which points to the first of 10 bytes in an auxiliary table, each pair of which points to an expression specified in relation to a certain attribute. They have this format:

Array PTR	Defined PTR	Initial PTR	Label PTR	Bit PTR
0-1	2-3	4-5	6-7	8-9

Each pointer is nonzero <=> the attribute associated with it has been specified, and an expression is related to it.

The flow chart has been written with the eventual goal of coding it into System 360 assembly language for use in the proposed PL-I console compiler.

J. L. Christopher

3.8 360 PL/I Terminals

Flow charts for the syntax check and formats for the output string have been devised for the following PL-I statement types:

DO, IF, PROCEDURE, ENTRY, and RETURN. The DECLARE statement flow charts have been finished.

A method has also been devised for completing the syntax check of IF statements in the second part.

The actual syntax check for the statement types above, in general, depends on previously flow-charted routines to check constants, expressions, and various attribute declarations.

The format of the output is some combination of arithmetic expressions in suffix form, pointers to the secondary buffer, and bit significance tables which either carry various information about the statement type or declaration or indicate the nature and arrangement of the pointers.

J. L. Christopher

3.9 Subroutines

The syntax check flow charts have been completed, and the work of converting the flow charts and some of the routines written by Demlow and Meyers for the 7094 into 360 assembly language has started.

Bill Demlow and I decided which registers would contain which pointers and have which functions.

So far, I have coded a subroutine called GETCHR, which puts the next character into general register 2 right justified, a macro named PUTCHR which stores the character in a buffer specified as a parameter. Both routines increment pointers, and a routine called LINNUM which tests for a legal line number of form XXX.XXX, puts the digits into the line number buffer right justified filling out to six characters by putting zeroes on the left. The actual line number entry is followed by the current address of the next available word in the output buffer which will contain the line corresponding to the line number.

J. L. Christopher

3.10 Character Programs

The present work has mainly been concerned with integration of the various input/output and character manipulation routines of the 7094 simulator of the PL/I Syntax Checker. The form of the 'Reverse Polish' output string has been finalized as follows. The first byte contains flags to the nature of the line (i.e. keyword or assignment statement), and to errors found. The second byte contains the length of the Polish string (in bytes). The third through eighth bytes contain the line number recoded from the form 'ABC.DEF' to the form ABCDEF. From this point on the 'Polish' string is of the form 0 to 2 bytes of information precedes each operator, identifier/keyword and constant in that order. The form for an operator is one byte of which the first three bits identify it as an operator and the last five bits identify

the specific operator. For an identifier or keyword, there is one preceding byte which identifies which of the two possibilities follows, whether or not the identifier or keyword is subscripted and the length of the identifier or keyword. In the case of a constant, two preceding bytes give information on the constant (i.e. fixed/float, binary/decimal/bit string/real or complex) and the length. At this time the form of a complex constant will be accepted as either a + bi or bi + a and will be recoded for output as one constant ab. 'a' and 'b' may be in any of the above modes except bit string.

Work is progressing on revisions of the routines to recognize identifiers and constants. These revisions are necessary to make these routines more flexible, and available to the rest of our programming group for a variety of purposes.

W. W. Demlow

3.11 360 Program Assembly Language

The present work has been concerned with the assembly language routines for the IBM 360.

Several suggestions have been brought up for consideration. One is to attempt to do a table-look-up character swap, from ASCII to our own code, in the PDP-7 instead of in the 360. This approach appears to be quite suitable for a small number of remote terminals. Whether it will still be feasible with a large number of terminals must be determined later. The second suggestion was to work with halfwords as much as possible within the 360 since this saves space and since the halfword instructions appear to be adequate for our purposes. Therefore, all the programming done so far works with halfwords rather than fullwords.

W. W. Demlow

3.12 Syntax Analyzer

Work continued on ironing out various details, writing and checking macros, and flowcharting. Currently the third version of a very detailed flow chart of the assignment statement scan is being checked.

The assignment statement is receiving most of the current effort. It is hoped that a workable SCATRE syntax scanner for the assignment statement will be in operation by June 1.

Also the output of the syntax scan--a reverse Polish string--will be suited to interpretation in a "stack-machine".

The present form of the intermediate string will be as follows:

1. Each operator will occupy 1 byte.
2. Each letter of an identifier will take 1 byte: the first three bits of the eight bits will give information as to
   a. break or non-break character (last letter in an identifier)
   b. alphabetic or numeric
3. Also there will be a byte of information before each identifier specifying
   a. subscripted or not
   b. length
4. Also there will be a byte of information before each line giving information about each line.

M. Meyers

3.13 Computer Graphics

3.13.1 338 Console

3.13.1.1 PDP-8 Clock

A clock was found to be installed in our PDP-8. The clock was made to work properly and the frequency of the clock was set to between 70 and 80 cycles per second. The software attributes of the clock are described in Display Users Memorandum-1.

3.13.1.2 PDP-8/PDP-7 Communications Link

In our PDP-8 we have an operational communications link to our PDP-8. This link has been checked out in hardware and in software. The programming attributes of the communications link are described in the Display Users Memorandum-2.

3.13.1.3 NEPAL Assembler

The NEPAL Assembler now exists in its complete form. All planned language features are implemented in the assembler. Normal software maintenance will be the only future work done on the assembler.

The NEPAL Assembler manual exists as Display Users Memorandum-3. This memorandum gives complete instructions for using the assembler. Copies of the binary deck of NEPAL are available for batch use and the time sharing version of the NEPAL assembler will be available under the read only system option of the BOOTS II time sharing system.

3.13.1.4 PDP-8 System

The PDP-8 system now exists in a usable condition. This program includes a complete interrupt processor, some display management routines, local teletype I/O routines, remote (ILLIAC II) I/O routines, a complete text manipulating routines for writing and updating programs, reports, etc., a routine to make the PBD-338 resemble a high speed time sharing terminal hooked to the ILLIAC II, BOOTS II time sharing system and a loader for PDP-8 programs or display files sent from ILLIAC II over the PDP-7/630 communications link. This system is described in the Display Users Memorandum-4 (to be issued).

Routines to handle DECTAPE I/O will be added to the system. Also a DECTAPE filing scheme will be integrated in the system.

F. K. Richardson

3.13.1.5 PDP-8 End of C.A.P.S

Since the PBD-338 hardware was available, actual running of the DRAWINg program and its subsidiary routines was made during this month. Some modification of the program has been made in order to get better display results. It is now working. The tracking cross program was also tested and modified. It is also working. The difficulty and time of debugging the programs were enhanced due to the malfunction of ILLIAC II's paper-punch unit.

Work under planning is the implementation of man-machine communication by using PBD-338's push buttons and its light pen. An initial set of modes to be associated with the push buttons is: MOVE, DELETE, CHANGE, ATTENTION and TEXT EDIT. The move mode is to be implemented first.

3.13.1.6 PDP-8 and PBD-338 of CAPS

Work continued on the implementation of some push-button function on PBD-338 in order to enable the man-machine communication for the display user concerning the flow-chart displays. Work was done in modifying the Drawing program so that it will accommodate to the possible changes in the entries of sources tables which it converts into display files to be displayed on the PBD-338. Also a minor change is done on the Drawing program so that it will have the characters in the decision or processor symbol to be placed around the center axis of the symbol resulting in better flow-chart display.

A proposed scheme to implement the Move mode will be to have several subroutines to take care of all the possible cases that might occur when a user indicates his desire to make some change on the display by pushing the push-button assigned to the Move mode on the PBD-338.

In Move mode the user is allowed to move or delete any symbol of his own flow chart display and is also allowed to add a new symbol to his flow-chart with some statement by pseudo move of the type of symbol displayed at some fixed location on the display face, which is called light button. Light buttons will never be moved or deleted by users, and they are the permanent symbols in Display file. All arrow type symbols are not allowed to move. A user can move an arrow of his own flow chart by moving either one of the symbols connected by the arrow. An attempt to move the arrow light button will be interpreted to append to the flow chart a new arrow symbol, and the computer will respond with blinking "To" and then "From" signals to ask the user to indicate to which two symbols to be connected by this new arrow symbol.

With the above implementation it is possible for a user to create a flow chart or alter any old one by simply using move mode, after display file is called into action.

After the Move mode is implemented, the Delete mode is almost implemented because functionally it is included in the Move mode.

It is in the coding phase of those routines for the "Move" and the "Delete" functions.

3.13.1.7 PBD-338 End of CAPS

The coding of the programs to handle the Move mode and the Delete mode of the push button for man-machine communication on PBD-338 has been

done during this month. The program to implememt the Move mode includes a routine to find out which symbol has been selected by the user using the light pen hit, a routine to enable the light pen hit for the tracking cross and disable the light pen for all other symbols and vice versa, a routine to append a new symbol to the source table, and a routine to allow the user to input text for the new added symbol via the teletype. Also included in this program are a routine to decrease and increase the intensity of all displayed symbols except the tracking cross, a routine to change the coordinates of the tracking cross and the selected symbol, and a routine to count the number of the continuous internal stops after a symbol is selected to provide a clue to decide when to fix the symbol. Shared by the Move mode and the Delete mode is a routine to delete a symbol from the Source Table and then compact the Source Table after the Drawing program is through its job. This routine is used in the Move mode when there is an edge flag caused either by the tracking cross or the moved symbol, or in the Delete mode after a symbol except the light button is selected by the light pen.

Each of these subroutines has been checked out on-line and the whole program is to be on-line debugged as soon as the installation of the DEC tape unit is finished on the PBD-338.

T. Y. Lo

3.13.2 CalComp Simulated Output for Display

The program, PLØT1 was prepared to transmit plot information from the ILLIAC II to the PDP-8. This program differs from the initial PLØT program in that the actual X,Y,Z coordinates are transmitted together with the intensity to be used rather than transmitting increments as is done in the previous programs. Either single or double precision may be used.

A written description of the PLØT-SYMBØL routine is also being prepared.

L. L. Koopman

An (X-Y-Z) perspective viewer, rotater, translator and magnifier program is being written for the 338. This will interface to PLOT1 described above.

C. W. Gear, P. Neuhaus

3.13.3 Numerical Systems - Ordinary Differential Equations

The differential equations program has been adapted to solve a particular system of equations which are stiffly stable. In the previous D.E.Q. package, the user needed only provide the subroutine to evaluate the functions. For the present program, another subroutine must be provided which calculates the value of

$$\left[I + \frac{h\beta_0}{\alpha_0} \right]^{-1}$$

where D is the matrix of the partial derivatives of the differential equations. The resulting matrix is used in the modification of the corrector formula.

The subroutine which performs the actual integration has been changed so that various tests are made to determine whether it is necessary to halve or double the step size or to re-evaluate the matrix

$$\left[I + \frac{h\beta_0}{\alpha_0} D \right]^{-1}$$

in order to effect convergence.

The subroutine to halve and double the step size are now combined in one which uses the factor .5 or 2 as a parameter.

The differential equations package has been altered as follows:

1. The program advances the solution of a system of equations until a specified interval in the independent variable has been traversed and then prints the values of the solution at that point. This periodic printing continues until a definite number of steps have been taken. Both the interval and the maximum number of steps to be taken are read in as data. This will facilitate plotting of the data obtained.

2. The specification for integrating a system of equations, which vary according to the accuracy, speed, and form of the results desired, can be read in as data. The order of the method to be used and the printing points and number of steps are read in once in any one run. The error to be allowed, number of iterations permitted and the number of attempts to integrate before allowing re-evaluation of the matrix:

$$\left[I + \frac{h\beta_0}{\alpha_0} D \right]^{-1}$$

can be changed as many times as desired in any one run (limited of course by the amount of time and output allowed).

3. Ordinarily, in order to start the integration the initial step size must be halved several times until it is sufficiently small to permit convergence. This is time consuming since each halving involves a call to a subroutine. The program now determines initially approximately how many times the step will have to be altered (by means of a relationship between the error to be permitted and the initial difference between the predictor and corrector). Then the step-changing subroutine performs the specified number of halvings in one call. The subroutine to halve the step size was changed since the previous version, when made to eliminate the successive halvings, was incompatible with the ability to print results at an exact specified interval.

K. Walsh

4. ILLIAC IV

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Summary

The major activity in hardware design for this period concerned final specifications for the PE instruction set. The new set requires a 32-bit instruction length to hold the function information, the operand address, the central register address for indexing, and a bit to distinguish between PE and CU executed instructions.

The functions for each register in the PE were redefined. Modifications were made to paths between registers so that any register in the PE can be loaded or stored without destroying others.

The PE mode bits are organized in an 8-bit register which can also be loaded or stored from other registers of the PE. The options for arithmetic instructions were re-examined relative to significance arithmetic and multiple precision operations. The extended add/sub instruction was slightly modified to speed up double length addition and subtraction.

The complement of broadcast addresses was made available to the index adder to simplify PE index testing and modification.

Eight-bit byte instructions will be implemented in such a way that carry propagation is diverted at every eighth bit position of the adder; all such carries at this point will be gated into a C register which is accessible for program and carry handling.

PE design has thus come to a well defined form and has been released to Texas Instruments for mask designs.

4.1 Software Introduction

During this quarter, a high level language for ILLIAC IV was proposed and discussed. The software group considered the problems of its translation and inconsistencies in its definitions. The applications group began to consider its usefulness for expressing algorithms. These considerations will lead to a redefinition of such a language.

The ILLIAC IV simulator on the 7094 continued to be coded and debugged. An assembler was also started. All of this work depends on final ILLIAC IV specification for its completion.

Preliminary thoughts were generated about a system to aid in the construction of a compiler. Much depends on the I/O computer to be used.

4.2 An ILLIAC IV Translator

4.2.1 Introduction

Translator development is proceeding in two basic areas: language specification and language translation.

4.2.2 Language Specification

The language proposed is procedure-oriented and is similar to ALGOL in that it involves the use of block structures and headings, assignment statements, go to statements, and conditional statements. ALGOL notation, however, has been partially changed. The FOR statement has been specified to allow for parallel as well as sequential operations, and declaration statements have been expanded to allow data partitioning and construction and to provide means to specify data structures.

A short program will illustrate some of the language features. The program determines for each J whether the dot product of the J^{th} row of two matrices, A and B, is positive, zero, or negative, where J ranges over the odd numbers between 2 and 76. When the result is positive, I ranges from 1 to 100, when zero from 110 to 200, and when negative from 1 to 100 and from 110 to 200. Then the arithmetic

calculation is A[I,J] + B[I,J] if A[I,I] > 0 or A[I,I] - $B[I,I]^2$ otherwise.

This program is:

```
"BEGIN
    "DECLARE  "ARRAY A[1:256],   B[1:256, 1:256], C[1:256, 1:256]
                "REAL  "FLOAT  "LONG  "SKEWED;
                S, S1, S2  "SET;
                I,J  "REAL "FIXED(B48);
                 T   "REAL "FLOAT "LONG;
    S1 ← (G:1 ≤ I ≤ 100)(I);
    S2 ← (G:110 ≤ I ≤ 200)(I);
    "FOR I ("SEQ ((G:1 ≤ K ≤ 37)(2K+1)) "DO
        "BEGIN
            T ← A(,I) "DOT B(,I);
            "IF T < 0 "THEN S ← S1  "ELSE  "IF
                T = 0 "THEN S ← S2  "ELSE S ← [S1,S2];
            "FOR I  "SIM  S  "DO
                C[I,I] ← A[I,I] + ("IF A[I,I]>=DO
                "THEN A[I,I] + B[I,I]
                "ELSE A[I,I] - B[I,I]*2;
        "END;
"END
```

4.2.3 Arithmetic Operations

It is planned to implement in the high level language fixed point operation for 8, 16, 24, 32, 64 bit words as well as double precision floating point operations. A number of short codes were written to perform some of these operations; they are listed below along with the estimated execution time in ILLIAC IV clocks (about 40 nanoseconds).

	Execution Time in Clocks	No. of Operands with All PE's Working
Significance Arithmetic Divide	98	256
Significance Arithmetic Multiply	28	256
64 to 32 Bit Floating Point Conversion	12	256
Double Precision Divide	195	128
8 Bit Divide	597	2048

A code was also written to find the mean of $256 \times M \times 8$ 8 bit words stored across the PE's; the total execution time is 120 M + 2100 clocks.

4.2.4 A Language Translator

The quarter was spent studying various syntax-directed systems, both theoretical and practically implemented. All were rejected as not completely meeting the present needs. Attempts are being made to combine the better features of these different systems and some ideas of our own. Among the systems receiving the most attention are the Ph.D. theses by Jerome Feldman of Carnegie Tech and W. M. McKeeman of Stanford.

4.2.5 Translator Generator

During this period, preliminary design work for the ILLIAC IV translator generator system was done. This necessarily involved a considerable search of the literature. A number of non-alterable compiler schemes were examined and rejected for the following reason: a user may need to define complex data structures and an intricate set of operations between data elements; it is desirable to have a modifiable compiler which may easily and quickly incorporate and efficiently code such operations. Thus, a generalized translator generator approach rather than the hand-coded approach to compiler production was chosen.

The translator generator will have four basic logically separate sections: the scanner, which breaks the input character string into the atoms (identifiers, literals, terminal symbols) of the language; a syntax part, which parses the input

stream after processing by the scanner; a semantic part, which translates the parsed output of the syntax part into an intermediate language which will be machine independent; and a machine description part, which translates the intermediate language into machine code. The scanner could be directly incorporated in the syntax and semantic parts, but this would not be as efficient as using a separate--and not so general--program.

Considerable effort has been spent in rendering the translator generator functionally modular. This effort is especially important to accommodate the various new ideas for language features engendered by continuing acquaintance with a computer of parallel structure.

4.3 Storage Allocation Studies

The matrix inversion and multiplication programs have been coded and timed. The inner loop of the matrix inversion program consists of three CU instructions and four PE instructions, i.e., 37 clocks, or 10^4 clocks to process 256×256 submatrix of a big matrix. Similarly, the inner loop of the matrix multiplication program consists of three CU instructions and four PE instructions, but requires 2×10^6 clocks to process a 256×256 submatrix.

To bring in 256×256 matrix from the ILLIAC IV, 10^5 clocks are assumed. To reduce the I/O time in the case of matrix inversion, the method of inverting each submatrix one by one is much preferred to inverting the whole matrix at once. In this case, 4×10^6 clocks would be necessary to process a 256×256 submatrix.

In both programs, three CAR registers are used, i.e., one for 256 counting and two for broadcasting.

4.4 SIMULATOR

The simulator instruction execution routine was coded. Op codes were assigned to the operations in a fashion which would allow efficient decoding of instructions.

A pseudo-monitor was written for the simulator and is now in the debug stage. The monitor handles user (simulator) decks according to user specifications to assemble, simulate the object program, punch object program in binary, etc.

It was decided that due to memory size limitations, the simulator system should consist of three separate core loads for the 7094: the assembler, the simulator, and the monitor. The monitor was designed with this in mind.

4.5 Display Software

A general contour mapping algorithm for ILLIAC IV has been devised. The algorithm operates on a matrix of data, and the results allow the matrix to represent an arbitrary geometry. Output is created for a vector generating CRT display. ILLIAC IV does all the heavy calculations in the algorithm in parallel and sends results to a GPC which orders the vectors. The ILLLIAC IV portion of the algorithm was written in assembly code.

APPLICATIONS

4.6 Introduction

In partial differential equations, the attention of applications efforts continued to be focused on the areas of hydrodynamic calculations, alternating direction methods, the Fourier technique of R. W. Hockney for the solution of Poisson's equation, and the S_n method of Carlson for neutron transport problems. To summarize the results achieved, simulator codes were completed for the Eulerian flow problem, the two dimensional alternating direction solution of the head equation, and for Hockney's method. In addition, numerical experiments related to local studies of the alternating direction methods were carried out to test several algorithms developed for tri-diagonal matrix inversion. Finally, investigations of Carlson's S_n method continued, particularly those related to the problem of determining the sequential ordering of the calculation. Also, preliminary programming ideas were generated concerning an underground blast wave propagation problem.

Several new meteorological problems were undertaken, some of which are of more practical interest than general circulation models.

Signal processing studies of seismometer arrays were continued. In particular, much attention was given to least squares and maximum likelihood filter design.

A genetics code was also begun. This model uses long vectors and does much rearranging of subvectors. It has much value as an ILLIAC IV programming study as well as its intrinsic value.

4.7 Partial Differential Equations

4.7.1 Alternating Direct Implicit Method

In an attempt to solve the heat equation on ILLIAC IV using the Alternating Direction Implicit method (ADI), several problems arose. The most recent of these problems concerns the storage needed when using Gaussian Elimination to invert a system of tridiagonal matrices. First the Gaussian Elimination method for tridiagonal matrices is summarized. Then the storage problem is discussed. Finally, possible solutions to the storage problem are shown.

Suppose $Ax = k$ where x is the vector to be determined, and

$$A = \begin{bmatrix} b_1 & c_1 & 0 & \cdots & 0 \\ a_2 & b_2 & c_2 & 0 & \cdots & 0 \\ 0 & a_3 & b_3 & c_3 & 0 & \cdots & 0 \\ & & & \ddots & & & \\ & & & & & c_{n-1} & \\ & & & & a_n & b_n & \end{bmatrix}$$

i.e., A is tridiagonal.

Now A = L · U can be written uniquely, where L is a lower triangular matrix and U is an upper triangular matrix.

$$L = \begin{bmatrix} \ell_1 & 0 & \cdots & 0 \\ a_2 & \ell_2 & 0 & \cdots & 0 \\ 0 & a_3 & \ell_3 & 0 & \cdots & 0 \\ & & \ddots & \ddots & \ddots & \\ & & & a_n & \ell_n \end{bmatrix}$$

$$U = \begin{bmatrix} 1 & u_1 & 0 & \cdots & 0 \\ 0 & 1 & u_2 & & \vdots \\ & & \ddots & \ddots & 0 \\ & & & 1 & u_{n-1} \end{bmatrix}$$

The a_i's are the a_i's from the matrix A and the ℓ_i's and u_i's in the matrices L and U, respectively, are related to a_i's, b_i's, c_i's of the matrix A as follows:

$$\ell_1 = b_1 \tag{1}$$

$$u_1 = c_1/\ell_1 \tag{2}$$

$$\ell_i = b_i - u_{i-1} \times a_i \tag{3}$$

$$u_i = c_i/\ell_i \ . \tag{4}$$

Once the ℓ_i's and u_i's are calculated then

$$Ax = L \cdot Ux = k.$$

If $Ux = z$, the equation $L \cdot U \cdot x = k$ can be written as

$$Lz = k \tag{5}$$

$$Ux = z \ . \tag{6}$$

Now using equation (5) vector z is given by

$$z_1 = k_1/\ell_1$$

$$z_i = (k_i - a_i \times z_{i-1})/\ell_i \ .$$

After the forward sweep has been made, i.e., the z vector calculated, the x vector may be calculated using equation (6) as follows:

$$x_n = z_n \tag{7}$$

$$x_{n-k} = z_{n-k} - u_{n-k} \times x_{n-k+1}. \tag{8}$$

Of concern is the storage of the vectors ℓ and u for each system of equations to be inverted. In particular, if an n × n tridiagonal system of equations to be solved, 2n-1 storage locations are needed to store ℓ and u. If ILLIAC IV is to invert 2n matrices, of order n × n, then ILLIAC IV will need 2n(2n-1) total storage locations just to store the vectors ℓ and u. On the other hand, if the ℓ and u vectors need not be stored, only 512 temporary locations are required. This is a considerable savings for large n. So, the question is, do the vectors ℓ and u need to be stored in order to invert the tridiagonal matrix? The answer is, "No," the vectors ℓ and u do not have to be stored.

The following procedure shows how the vector x may be determined without storing any ℓ_i's or u_i's.

Let

$$\ell = b_1$$

$$U = c_1/\ell$$

$$z_1 = k_1/\ell.$$

Now the loop is formed

$$\ell = b_i - u \times a_i$$

$$u = c_i\ \ell$$

$$z_i = (k_i - a_i \times z_i)/\ell$$

for

$$i = 2, 3, \ldots, n.$$

When the end of this loop is reached, the vector z has been calculated in the forward sweep. The last u calculated is actually u_n, and the last ℓ is ℓ_n. Now the backward sweep is performed and solution vector x is calculated by

$$x_n = z_n.$$

The next loop formed is

$$j = n-1$$

$$u = (b_j - \ell)/a_j$$

$$\ell = c_j/u$$

$$x_j = z_j - u \times x_{j+1}$$

for

$$j = n-1,\ n-2,\ \ldots,\ 1.$$

Hence after this loop has terminated, the vector x has been solved.

There is one problem with this method. On the backward sweep the roundoff error grows to such an extent that if n is very large all the accuracy is lost in the solution vector. This problem of roundoff error can be handled in several ways. Table 1. shows the roundoff error from five methods used to invert a tridiagonal matrix. The table was calculated using the following system Ax = k where:

$$A = \begin{bmatrix} 1 & -\frac{1}{2} & 0 & \cdots & 0 \\ -\frac{1}{2} & 1 & -\frac{1}{2} & 0 & \cdots & 0 \\ 0 & -\frac{1}{2} & 1 & -\frac{1}{2} & 0 & \cdots & 0 \\ & & & & & -\frac{1}{2} \\ & & & & -\frac{1}{2} & 1 \end{bmatrix}$$

and

$$k = \begin{bmatrix} \frac{1}{4} \\ 0 \\ \vdots \\ 0 \\ \frac{1}{4} \end{bmatrix}$$

The order of A was initially 100 x 100, then 500 x 500, and finally 1000 x 1000. One special case used was 5000 x 5000. All calculations were made on the IBM 7094.

TABLE 1.

1. The vectors ℓ and u were stored.

Size	Maximum Error	Average Error
100 x 100	5.7×10^{-7}	3.7×10^{-7}
500 x 500	2.3×10^{-6}	9.8×10^{-7}
1000 x 1000	6.9×10^{-6}	3.05×10^{-6}

2. The vector u was stored and double length accumulations used. (All subscripted variables stored in single precision).

Size	Maximum Error	Average Error
100 x 100	$9. \times 10^{-8}$	6×10^{-8}
500 x 500	3.8×10^{-7}	2.5×10^{-7}
1000 x 1000	7.3×10^{-7}	4.9×10^{-7}

3. The vectors ℓ and u were not stored. Single length accumulation was used.

Size	Maximum Error	Average Error
100 x 100	4.6×10^{-4}	2.5×10^{-5}
500 x 500	4.7×10^{-2}	7.5×10^{-4}
1000 x 1000	2.97×10^{-1}	3.5×10^{-3}

TABLE 1. (CON'TD)

4. The vectors ℓ and u were not stored, and double length accumulation was used. (All subscripted variables are stored in single precision).

Size	Maximum Error	Average Error
1000 x 1000	0	0
5000 x 5000	1.9×10^{-7}	0

5. On the 100 x 100 system, 3 u values were saved, i.e., u(25), u(50), u(75), and the errors were:

Maximum Error	Average Error
4.28×10^{-6}	1.26×10^{-6}.

By storing only the 3 intermediate values of u, the maximum and average errors are factors of 10^2 and 10, respectively, better than where no values of u were stored.

For the 500 x 500 system every tenth value of u was stored and the errors were:

Maximum Error	Average Error
3.38×10^{-6}	1.4×10^{-6}.

Here a factor of 10 is gained in storage, but a factor of 10 is lost in both maximum and average error over the method where u_i's are stored.

For the 1000 x 1000 system every tenth value of u was stored and the errors were

Maximum Error	Average Error
1.2×10^{-5}	6.77×10^{-6}.

Here a factor of 10 is gained in storage, but a factor of 10^2 is lost in maximum error and a factor of 10 is lost in the average error over the method where all the u_i's are stored.

In conclusion the solution of any system of 5000 x 5000 or less is best done by storing no u(I) values, and using double length accumulation. The only disadvantage of this method is that it will, no doubt, require more time. Other than this one drawback, it looks as if this is by far the best method.

4.7.2 Hockney's Method

This method can best be understood by looking at the following outline of the states in the calculation. Table 2 gives the formulae at each step and Fig. 1, the storage picture and routing information.

The calculation procedure involves ten stages.

1. Odd even Reduction: The number of equations is reduced to one-half as many more complicated equations for the unknown potential on the even numbered lines of the mesh only. A modified charge distribution replaces the original on these lines.

2. Fourier Analysis: A Fourier transformation is made on these equations, and the Fourier transform of the modified charge distribution on the even lines overwrites the modified charge distribution.

3. Recursive Cyclic Reduction: The equations are combined and the number of them reduced by one-half recursively until there are only three equations.

4. Solve 3 x 3 Matrix: This is done directly.

5. Recursive Backsubstitution: The three solutions found in stage (4) are substituted into the previous equations of stage (3). This continues recursively back through each step of stage (3) until the 48 harmonic amplitudes on all 24 of the even lines have been found.

6. Fourier Synthesis: The harmonic amplitudes are used to get the desired potential distribution on the even lines.

7. Odd-Line Modified Charge Distribution: The potential distribution on the even lines is used to form a modified charge distribution on the odd lines.

8. Recursive Cyclic Reduction: The 24 equations on the odd lines are combined recursively as above until there are only three equations.

9. Solve 3 x 3 Matrix: Solved directly as above.

10. Recursive Backsubstitution: Same as for the even lines. This gives the desired potential distribution on the odd lines.

TABLE 2.

STAGE	STEPS	INPUT	FORMULAE	OUTPUT
Odd/Even Reduction	$i=0(1)47$ $j=0(2)46$	$q_{i,j}, q_{i\pm1,j}, q_{i,j\pm1}$	$q_{i,j}^{*}=q_{i,j-1}-q_{i-1,j}+4\,q_{i,j}$ $-q_{i+1,j}+q_{i,j+1}$	$q_{i,j}^{*}$
Fourier Analysis	$k=0(1)24$ $j=0(2)46$	$q_{0,j}^{*}, q_{1,j}^{*}, \cdots, q_{47,j}^{*}$	$\bar{q}_{k,j}^{*c(1)}=\frac{2}{48}\sum_{i=0}^{47} q_{i,j}^{*}(\cos)\frac{2\pi ki}{48}$ $\bar{q}_{k,j}^{*s(1)}=\frac{2}{48}\sum_{i=0}^{47} q_{i,j}^{*}(\sin)\frac{2\pi ki}{48}$ $\lambda_k^{(1)}=-2(8-8\cos\frac{2\pi k}{48}+\cos\frac{4\pi k}{48})$	$\bar{q}_{k,j}^{*c(1)}$ $\bar{q}_{k,j}^{*s(1)}$ $k\neq0, k\neq24$ $\lambda_k^{(1)}$
Recursive Cyclic Reduction	$t=1(1)3$ $j=0(2^{t+1})(48-2^{t})$	$\lambda_k(t+1)=2-(\lambda_k^{(t)})^2$		$\lambda_k^{(t+1)}$

$$\begin{cases} k=0(1)24, \text{for } c \begin{cases} \bar{q}_{k,j}^{*c(t)}, \bar{q}_{k,j\pm2^t}^{*c(t)} \end{cases} & \bar{q}_{k,j}^{*c(t+1)}=\bar{q}_{k,j-2^t}^{*c(t)}-\lambda_k^{(t)}\bar{q}_{k,j}^{*c(t)}+\bar{q}_{k,j+2^t}^{*c(t)} \begin{cases} \bar{q}_{k,j}^{*c(t+1)} \\ \bar{q}_{k,j}^{*s(t+1)} \end{cases} \\ k=1(1)23, \text{for } s \begin{cases} \bar{q}_{k,j}^{*s(t)}, \bar{q}_{k,j\pm2^t}^{*s(t)} \end{cases} & \bar{q}_{k,j}^{*s(t+1)}=\bar{q}_{k,j-2^t}^{*s(t)}-\lambda_k^{(t)}\bar{q}_{k,j}^{*s(t)}+\bar{q}_{k,j+2^t}^{*s(t)} \end{cases}$$

(Henceforth assume K=k for c terms, K=k+24 for s terms. For example, $\bar{q}_{16,j}^{*}=\bar{q}_{16,j}^{*c}$ and $\bar{q}_{30,j}^{*}=\bar{q}_{6,j}^{*s}$ and $\bar{\varphi}_{47,j}=\bar{\varphi}_{23,j}^{s}$).

Solve 3x3 Matrix	$K=0(1)47$	$\bar{q}_{K,0}^{*(4)}, \bar{q}_{K,16}^{*(4)}, \bar{q}_{K,32}^{*(4)}, \lambda_K^{(4)}$	$\alpha_{K,1}=\frac{\bar{q}_{K,0}^{*(4)}+\bar{q}_{K,16}^{*(4)}+\bar{q}_{K,32}^{*(4)}}{3(\lambda_K^{(4)}+2)}$	$\bar{\varphi}_{K,0}, \bar{\varphi}_{K,16}, \bar{\varphi}_{K,32}$

(TABLE 2. CONTINUED)

STAGE	STEPS	INPUT	FORMULAE	OUTPUT
			$\alpha_{K,2}=\dfrac{\bar{q}^{*(4)}_{K,0}-2\bar{q}^{*(4)}_{K,16}+q^{*(4)}_{K,32}}{6(\lambda_K^{(4)}-1)}$	
			$\alpha_{K,3}=\dfrac{\bar{q}^{*(4)}_{K,0}-q^{*(4)}_{K,32}}{2(\lambda_K^{(4)}-1)}$	
			$\bar{\varphi}_{K,0}=\alpha_{K,1}+\alpha_{K,2}+\alpha_{K,3};\bar{\varphi}_{K,16}=\alpha_{K,1}-2\alpha_{K,2}+\alpha_{K,3};\bar{\varphi}_{K,32}=\alpha_{K,1}-\alpha_{K,3}$	
Back-Substitution	$t=3(-1)1$ $j=2^t(2^{t+1})(48-2^t)$ $K=0(1)47$	$\bar{q}^{*(t)}_{K,j},\bar{\varphi}_{K,j\pm2^t},\lambda_K^{(t)}$	$\bar{\varphi}_{K,j}=\dfrac{1}{\lambda_K(t)}\left(\bar{q}^{*(t)}_{K,j}-\bar{\varphi}_{K,j-2^t}-\bar{\varphi}_{K,j+2^t}\right)$	$\bar{\varphi}_{K,j}$
Fourier Synthesis	$i=0(1)47$ $j=0(2)46$	$\bar{\varphi}_{0,j},\ldots,\bar{\varphi}_{47,j}$	$\varphi_{i,j}=\frac{1-c}{2}\bar{\varphi}_{0,j}+\frac{1-c}{2}\bar{\varphi}_{24,j}(-1)^i+\sum_{k=1}^{23}\left(\bar{c}\bar{\varphi}_{k,j}\cos\frac{2\pi ki}{48}+\bar{s}\bar{\varphi}_{k,j}\sin\frac{2\pi ki}{48}\right)$	$\varphi_{i,j}$
Odd-Line Modified Charge	$i=0(1)47$ $j=1(2)47$	$q_{i,j},\varphi_{i,j\pm1}$	$q^{*(0)}_{i,j}=q_{i,j}-\varphi_{i,j-1}-\varphi_{i,j+1}$	$q^{*(0)}_{i,j}$
Recursive Cyclic Reduction	$t=1(1)4$ $j=1(2)47$		$\lambda_j^{(1)}=-4,\lambda_j^{(2)}=-14,\lambda_j^{(3)}=-294,\lambda_j^{(4)}=-86434$	$\lambda_j^{(t)}$
	$i=0(2^t)(48-2^t)$	$q^{*(t-1)}_{i,j}$	$q^{*(t)}_{i,j}=q^{*(t-1)}_{i-2^{t-1},j}-\lambda^{(t-1)}q^{*(t-1)}_{i,j}+q^{*(t-1)}_{i+2^{t-1},j}$	$q^{*(t)}_{i,j}$

(TABLE 2. CONTINUED)

STAGE	STEPS	INPUT	FORMULAE	OUTPUT
Solve 3×3 Matrix	$j=1(2)47$	$q^{*(4)}_{0,j}, q^{*(4)}_{16,j}, q^{*(4)}_{32,j}, \lambda^{(4)}_j$	$\alpha_{j,1}=\frac{q^{*(4)}_{0,j}+q^{*(4)}_{16,j}+q^{*(4)}_{32,j}}{3(\lambda^{(4)}_j+2)}$ $\alpha_{j,2}=\frac{q^{*(4)}_{0,j}-2\,q^{*(4)}_{16,j}+q^{*(4)}_{32,j}}{6(\lambda^{(4)}_j-1)}$ $\alpha_{j,3}=\frac{q^{*(4)}_{0,j}-q^{*(4)}_{32,j}}{2(\lambda^{(4)}_j-1)}$ $\varphi_{0,j}=\alpha_{j,1}+\alpha_{j,2}+\alpha_{j,3};\ \varphi_{16,j}=\alpha_{j,1}-2\alpha_{j,2}+\alpha_{j,3};\ \varphi_{32,j}=\alpha_{j,1}-\alpha_{j,3}$	$\varphi_{i,j}$
Back Substitution	$t=3(-1)0$ $j=1(2)47$ $i=2^t(2^{t+1})(48-2^t)$	$q^{*(t)}_{i,j}, \lambda^{(t)}_j, \varphi_{i\pm 2^t,j}$	$\varphi_{i,j}=\frac{1}{\lambda^{(t)}_j}\left(q^{*(t)}_{i,j}-\varphi_{i-2^t,j}-\varphi_{i+2^t,j}\right)$	$\varphi_{i,j}$

The following are the symbol definitions in terms of the formulae of Fig. 1.

$\cdot = q_{i,j}$ $\quad \Delta = \bar{\varphi}^{c}_{k,j}$ $\quad —(n)\rightarrow$ = "then the n^{th} stage is performed resulting in ..."

$\bullet = q^{*}_{i,j}$ $\quad \square = \bar{\varphi}^{s}_{k,j}$

= the interaction module at this stage for a sample point

$\blacktriangle = \bar{q}^{*c}_{k,j}$ $\quad \circ = \varphi_{i,j}$

$\blacksquare = \bar{q}^{*s}_{k,j}$ $\quad '$ (prime) = level in recursive cyclic reduction

Note a: In the assembly code version the matrix is folded here instead of at the p.e. quadrant boundary to simplify routing and calculation of indices. Also note that problem has been reduced to 1/4 to simplify the drawings.

Note b: The following is a sample column from the 48 × 48 problem:

Note c: The following is a sample column from the 48 × 48 problem:

Figure 1.

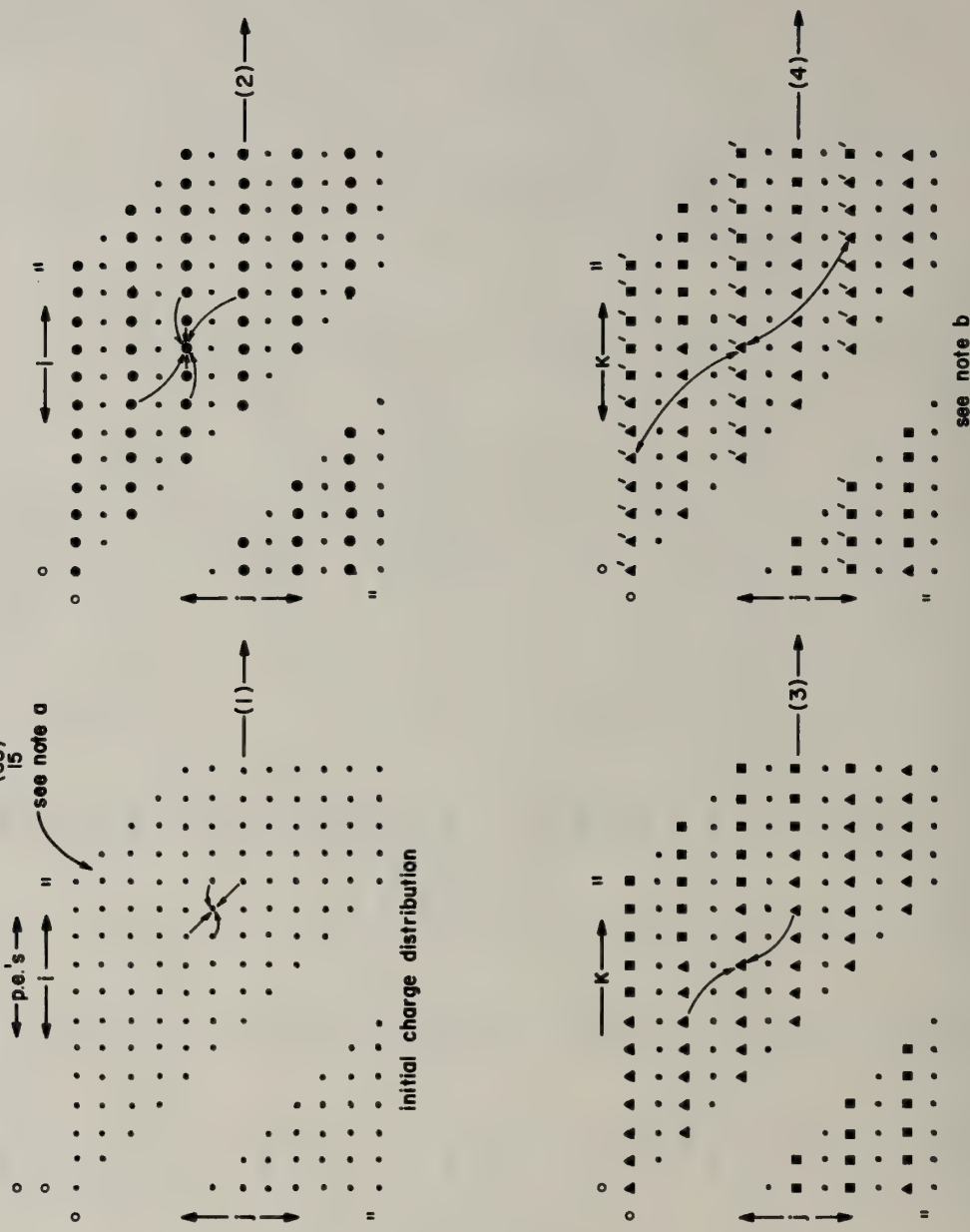

Figure 1 (Cont.)

FIGURE 1 (CONT.)

Figure 1 (Cont.)

Figure 1 (Cont.)

4.7.3 Carlson's S_n Method

The numerical solution of the steady-state neutron transport equation by Carlson's discrete S_n method in isotropic media and spherical geometry gives rise to the following difference scheme:

$$\left(\bar{\mu} + \frac{b_n}{\Delta_n}\frac{\Delta_j}{\langle r_j\rangle} + \frac{\sigma_j\Delta_j}{2}\right)\varphi_j + \left(-\bar{\mu}_n + \frac{b_n}{\Delta_n}\frac{\Delta_j}{\langle r_j\rangle}\frac{\sigma_j\Delta_j}{2}\right)\varphi_{j-1} = \Delta_j S_j + \left(\frac{2b_n}{\Delta_n}\frac{\Delta_j}{\langle r_j\rangle}\right)\varphi_{n-1}$$

where the terms are defined in the previous quarterly report.

More specifically, the source term S is:

$$S = \sigma_{99}\bar{\varphi} + \chi_9 F + \sum_h \sigma_{hg}\bar{\varphi}_h$$

where h = g are group indices. Here $\bar{\varphi} = \frac{1}{N}\sum_n^N \varphi_n$, the flux averaged over all directions within a group. The term $\bar{\varphi}_n$ is the same average for group h.

It is proposed to determine the φ's for all groups simultaneously. After the φ's have been calculated, the terms $\bar{\varphi}$ and $\bar{\varphi}_h$ of S will be updated. If we assume upscattering cannot occur, $\sigma_{hg} = 0$ when $h > g$, where g = 1 refers to the fastest group. An added simplification is to assume that neutrons scatter down only from group g-1 to group g. Once the φ's are calculated for all groups a fixed number of times, $F = \sum_g \nu\sigma_g b\bar{\varphi}_g$ is updated along with the remaining terms of S until convergence is attained.

4.7.4 Blast-Wave Propagation Problem

Investigation of a PDE problem being studied by Ahmed Sameh of the Engineering Department concerning blast-wave propagation through an elastic-plastic material led to the coding of a much simplified version of the problem in assembly language for ILLIAC IV as well as for Sankin's simulator at Burroughs. A similar simplified version was also coded in higher level language. Finally a version of the complete numerical solution was coded in higher level language, and, at this stage, it was realized that further work was necessary to devise new numerical methods so as to take fuller advantage of ILLIAC IV's parallelism.

4.8 Meteorology

This quarter marks the beginning of ILLIAC IV's study of meteorological topics other than general circulation modeling. Although the major part of meteorological computing time is devoted to the complex calculations of global flow development by primitive equations, computer applications in the atmospheric sciences are by no means restricted to this area. Thus, members of the ILLIAC IV group are now working on techniques for the study of the relatively small scale effects of radiation and turbulence. In addition, attention has been directed towards statistical analysis and forecast methods, specifically, one developed at the University of Wisconsin by Kutzbach and Wahl which describes the atmosphere with the coefficients of a Fourier-Bessel expansion.*

4.9 Signal Processing

The papers relating to LASA signal processing were studied. Lincoln Laboratories reported that the next large seismic array to be built was committed to widely spaced seismometers, so that their signals would be stochastically independent. This resulted in data processing techniques which are so simple that they are uninteresting. The present LASA in Montana was expected to be modified to conform to the above description also.

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* Journal of Applied Meteorology, 4:4 (August, 1965), pp. 542-544.

A possible third LASA is not yet committed as to the spacing of its seismometers, so there is a remote possibility that signal processing through cross correlation filtering will again come into vogue.

During this period the Cooley-Tukey algorithm was programmed for Sankin's simulator. Results of the simulation showed that 4 CAR's and 1 PE index provided sufficient indexing capability to insure that PE computations would not be unduly held up by CU operations. A revised program was even more efficient in this respect.

The problem of performing simultaneous matrix operations on many small matrices (such as would be entailed by a LASA system of subarrays) was considered. It was ascertained that this problem could be implemented without much difficulty.

4.10 Population Genetics

During this period time was spent mainly on the initial stages of a problem in the application of the ILLIAC IV concept to problems in populational genetics. The primary aim of this study was the generation of a generalized program that would simulate a chromosomal level genetic population and allow the experimenter to subject that population to controlled variations in reproduction patterns, mutation, and selection such that the detailed genetic and phenotypic effects of these factors could be studied. The basis of this effort was a similar, though much less involved or accurate simulation currently being developed on the IBM 7094. A preliminary investigation was made to determine the relationships between the various requirements of the program and the operating features of the ILLIAC IV. By June these had been more or less finely determined in certain areas, without the production of any machine code, but was quite unclear in certain other segments of the program.

APPENDIX A

Bibliography of ILLIAC IV Documents Published During the Quarter

Doc. No.	Title	Author	Date
100	A Source Language Program for Robinson's Algorithm	Robert Carr	April 2, 1967
115	ILLIAC IV Simulator System	L. E. Anderson	April 10, 1967
117	Programming Remarks for the Present ILLIAC IV Specification	M. Kato	April 14, 1967
119	Viewgraphs: SJCC Slides (Software and Hardware)		April, 1967
120	A Comparison of Operation Counts and Error Analysis of Robinson's Algorithm and the Algorithm of Wiggins and Robinson	Robert Carr	April 24, 1967
121	Gauss-Seidel on ILLIAC IV	Robert Carr	May 1, 1967
122	Tentative ILLIAC IV Instruction Set	R. E. Marks	May 10, 1967
123	Burroughs' Ideas on Multi-Precision, Significance Arithmetic, and Multiplication	Burroughs Corp.	May 11, 1967
124	Notes on Byte Operations in the ILLIAC IV	J. P. Blondeau	May 25, 1967
125	A Preliminary Search for an Accurate Method for Solving Very Large Systems of Linear Programming	Robert Carr	June 16, 1967
126	An Algorithm of Wiggins and Robinson	Robert Carr	April 10, 1967
127	October, November, December 1966 Quarterly Progress Report		June 21, 1967

(Bibliography CONTINUED)

Doc. No.	Title	Author	Date
128	A "High Level Language" Problem	Paul Budnik	June 19, 1967
129	Significance Arithmetic	Paul Budnik	June 30, 1967
130	Addressing and Dynamic Coupling for the ILLIAC IV - A Proposal	L. E. Anderson	June 26, 1967
131	Counting Ones in an ILLIAC IV Word	Duncan Lawrie	June 27, 1967
143	Technical Specification for the ILLIAC IV Computing System (Revision A)	Burroughs Corp.	May 22, 1967
144	Technical Specification for the ILLIAC IV Computing System (Revision B)	Burroughs Corp.	June 14, 1967

5. NUMERICAL METHODS, COMPUTER ARITHMETIC AND ARTIFICIAL LANGUAGES

(Supported in part by the National Science Foundation under Grant No. NSF-GP-4636.)

5.1 Numerical Analysis

Experimental investigations were carried out to determine the average (as opposed to asymptotic) rate of convergence of the sequential extrapolated implicit method (SEI) for the solution of linear systems arising from the discretization of various boundary value problems for elliptic partial differential equations. The results of these investigations together with related results reported in this section of previous Quarterly Reports were assembled into a doctoral dissertation, which will be issued as a report in the near future.

(L. K. McDowell)

5.2 Computerized Mathematics

In the last quarter we continued our search for a practical decision procedure for the following question: given a set of polynomials $S:(A_1, A_2, \ldots, A_m)$ in several unknowns and a polynomial B, does the set S imply B. There do exist decision methods for the problem which was considered.

The first method considered was Tarski's method for elementary algebra. This method is based on elimination of quantified variables in a logical sentence by means of transforming a formula into an equivalent one involving only free variables occurring in the original sentence. The essential idea is to consider separately all the possible relations among the coefficients. For this reason, the intermediate formulas grow very rapidly. Also, the method is valid for real variables only. For these reasons, this method was discarded as two inefficient to be practical. In considering it, however, we were able to give a simpler, more intuitive proof of the validity of one of the transformations used.

The second method considered was based on the Sylvester's determinant condition for two polynomials to have common roots. In this method, the polynomials are treated as polynomials in one of the variables with coefficients polynomials in the remaining variables. The coefficients are then used to form a Sylvester's determinant, the vanishing of which is a necessary and sufficient condition for there to be common roots of the original system. Setting the determinant equal to zero, a new set of polynomials is obtained in which the eliminated variable does not appear. The process is then repeated until all variables have been eliminated, and a single equation a = 0 is left where "a" is a constant. This method is also subject to explosive growth both in the number of equations and degree of intermediate polynomials, so it was also discarded.

The method currently under consideration is a method based on the Euclidean algorithm. In this method we again single out one variable to be eliminated from the system $A_1, A_2, \ldots A_m$. Then A_1 and A_2 are replaced by the last two remainders A'_1, A'_2 when we apply the Euclidean algorithm to A_1, A_2. Then A'_1, A_3 are used to produce A''_1, A'_3, etc. until the variable chosen appears only in the first equation. Then the next variable is then eliminated from $A'_2, \ldots A'_m$, and so on. In this method, the number of equations remain constant, although the degree of the equations may increase rapidly. All solutions of the original system are solutions of the reduced system, but the process may introduce extraneous roots so the converse of the above statement is not true. However, one can find all the common solutions of the original system among the solutions of the reduced system by trial and error. In regard to extraneous roots we have found some errors in recent computing literature. We have discovered precisely how the Euclidean algorithm applied to two polynomials A and B introduces extraneous solutions.

(L. J. Henschen)

5.3 Autonomous Arithmetic Unit Structures

A more detailed analysis of the set of micro-instructions which the data processing units must perform was begun. Detailed flow charts for each possible floating point arithmetic operation are being prepared to determine if look-ahead is necessary in the primitive control unit.

The preparation of a report of this investigation has just begun.

(M. J. Pisterzi)

5.4 Algebraic Manipulation

During the last quarter the improvement of the routines comprising the IL5 list processor described in the previous Quarterly Report was continued. In the first month most of the work was involved with problems piecing together the overlays and with the addition of a trace feature, a combination dump and 'garbage collection' routine and subroutines to facilitate the comparison of operating characteristics of procedures. The IL5 list processor is currently capable of being used as an on-line interactive system but has not been able to be used as such due to problems in the Illiac II time sharing system.

A number of test programs in IL5 have been written and successfully run. Three of the more important ones which will be useful later are a general tree structured data output procedure, its inverse, an input procedure, and a syntactic analyzer. The latter is in principle similar to Feldman's compiler-compiler* but differs radically in the input format for the productions, in the method of performing the syntactic analysis and in that a list structure rather than compiled code is the final result. Also, the semantic conversation routines are written in IL5 code rather than in the formal semantic language of Feldman. The initial use of the syntactic analyzer is to recompile the originally hand-coded syntax loader consisting of the 20 productions describing the syntax of the analyzer itself. Once this bootstrap operation is finished and certified, extensions to the analyzer and the definition of languages for inputting algebraic expressions will be simplified.

The formulation of conventions on data representation for algebraic expressions is currently in progress. Flexibility is being stressed so that transformations such as lexicographical ordering, conversion from one canonical form to another and identity removal can be satisfactorily implemented. In particular, provisions are being made to allow polynomials

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* Feldman, J. A., "A Formal Semantics for Computer Languages and Its Application in a Compiler-Compiler," Comm. ACM, Vol. 9, No. 1, January, 1966, p. 3.

to be represented in data structures ranging from the condensed ALPAK sum of product canonical form to the recursive canonical form used in PM. (S. Nuspl)

5.5 Theory of Arithmetic Unit Structures

The following Ph.D. thesis was completed during the quarter:

> A Study of Transformation Applicable to the Development of Limited Carry-Borrow Propagation Adders
> by Fred Rohatsch.

The following paper was prepared for presentation at the First Annual IEEE Computer Conference, Chicago, Illinois, September 6-8, 1967:

> A Deterministic Procedure for the Design of Carry-Save Adders and Borrow-Save Subtracters
> by James E. Robertson.

The abstract of the thesis and the text of the paper are incorporated in this report in the following pages.

5.5.1 A Study of Transformations Applicable to the Development of Limited Carry-Borrow Propagation Adders

The dissertation presents the results of a study of a class of transformations applicable to the operations of addition and subtraction in parallel digital computers utilizing redundant number representations in the arithmetic unit.

The dissertation is organized into three main sections presented in sequence. The first section includes the definition, development, and study of a class of transformations on sets of real numbers. The second section is concerned with the application of the transformations to addition and subtraction. It is shown that the utilization of any redundant and contiguous sum/difference digit sets (the sets of digital values used in given number representations) makes possible the implementation of limited carry/borrow addition and subtraction, that is, addition and subtraction for which carries/borrows propagate no further than a fixed number (usually one or two in practice) of digital positions. The primary function of the second section is the development, by an example, of a systematic procedure for finding some limited carry/borrow propagation adders subject to specified operand and sum/difference

digit sets. The same procedure is applicable whatever the number of input operands may be.

The third section presents the results of a study of some statistical properties of a few selected adders; the purpose of the study being to determine probabilistic distributions of sum digits given the distributions of operand digits, and to examine the effect of repeated uses of an adder on such distributions.

5.5.2 A Deterministic Procedure for the Design of Carry-Save Adders and Borrow-Save Subtracters

The abstract and complete text follows.

A DETERMINISTIC PROCEDURE FOR THE DESIGN OF CARRY-SAVE ADDERS AND BORROW-SAVE SUBTRACTERS

by

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ABSTRACT

A recently developed deterministic procedure will be described, and employed to determine binary carry-save adder and borrow-save subtracter designs. Designs believed to be new as well as those previously known will be developed. A particular structure, expressed in terms of normalized digit sets, leads to three practical algebraic structures. Each of these in turn leads to nine (not necessarily unique) logical designs. Examples will be given and possible application to variable field length systems will be discussed.

1. REVIEW

Historically, the design of carry save adders and borrow save subtracters has been conducted by modification of conventional adders with propagating carry and of subtracters with propagating borrow. As an example, the Boolean equations for the ith digital position of a binary subtracter with propagating borrow are

$$\begin{aligned} s_i &= a_i \oplus m_i \oplus b_i \\ b_{i-1} &= \bar{a}_i b_i \vee b_i m_i \vee m_i \bar{a}_i \end{aligned} \quad , \tag{1}$$

in which a_i is a minuend digit, m_i is a subtrahend digit, s_i is a difference digit, and b_i and b_{i-1} are respectively the incoming and outgoing propagating borrow. Equations (1) are the Boolean equivalent of the algebraic expression:

$$-2b_{i-1} + s_i = a_i - m_i - b_i \tag{2}$$

The direct modification to a borrow save subtracter is one of associating with the a_i stored borrow digits α_i, and associating with the s_i stored borrow digits σ_i. Equations (1) then become

$$\begin{aligned} s_i &= a_i \oplus m_i \oplus \alpha_i \\ \sigma_{i-1} &= \bar{a}_i \alpha_i \vee \alpha_i m_i \vee m_i \bar{a}_i \end{aligned} \tag{3}$$

in which, as before, m_i is a subtrahend digit, but now the minuend is represented by the appropriately weighted sum of the digits a_i and α_i, and the difference is represented by the weighted sum of the digits s_i and σ_i. If the digits s_i and σ_i are associated to form a redundantly represented digit s_i^* in accordance with the formula $s_i^* = s_i - \sigma_i$, the possible values of s_i^* are -1, 0, and 1.

A less obvious modification to a borrow save subtracter is achieved by rewriting Equations (1) and substituting as follows:

$$s_i = a_i \oplus m_i \oplus b_i$$

$$b_{i-1} = (\overline{a_i \oplus m_i})b_i \vee \bar{a}_i m_i \qquad (4)$$

Let

$$\left.\begin{aligned} k_i &= (\overline{a_i \oplus m_i})b_i \\ b_{i-1} &= k_i \vee \bar{a}_i m_i \\ s_i &= (a_i \oplus m_i) \oplus (k_{i+1} \vee \bar{a}_{i+1} m_{i+1}) \\ k_i &= (\overline{a_i \oplus m_i})\cdot(k_{i+1} \vee \bar{a}_{i+1} m_{i+1}) \end{aligned}\right\} \qquad (5)$$

If, in Equations (5), the input propagating borrow k_{i+1} is replaced by a stored borrow α_{i+1} in association with a_{i+1}, and the output propagating borrow k_i is replaced with a stored borrow σ_i in association with s_i, the Boolean equations for the stored borrow subtracter become

$$\begin{aligned} s_i &= (a_i \oplus m_i) \oplus (\alpha_{i+1} \vee \bar{a}_{i+1} m_{i+1}) \\ \sigma_i &= (\overline{a_i \oplus m_i})\cdot(\alpha_{i+1} \vee \bar{a}_{i+1} m_{i+1}) \end{aligned} \qquad (6)$$

In Equations (6), the combination $s_i = 0$, $\sigma_i = 1$, cannot occur, hence a redundantly represented digit $s_i^* = -2\sigma_i + s_i$ may assume only the three values -1, 0, and 1.

As is evident from the expression for b_{i-1} in Equations (4), the propagating borrow must necessarily pass through an AND circuit and an OR circuit in each digital position. The stored borrow of the subtracter of Equations (3) is the output of the OR circuit; the stored borrow of Equations (6) is the output of the AND circuit; thus the subtracter structures require equivalent hardware. The relationship $\sigma_i \bar{s}_i = 0$ implied by Equations (6) simplifies the circuitry for conversion of the difference, represented by the s_i and σ_i, to conventional (non-redundant) form, and is therefore preferable if separate circuitry is provided for conversion.

2. THE DETERMINISTIC PROCEDURE

The purpose of the following sections is to describe a deterministic procedure for the design of carry-save adders and borrow-save subtracters. In the case of binary subtracters, which are chosen for specific examples, the procedure is shown to result in not only the two designs described in the previous section, but in new designs as well. The procedure involves three stages of design, as follows:

1) Specification in terms of normalized digit sets,
2) Choice of specific algebraic values, and
3) Logical design with specific binary formats.

For the purposes of this paper, an n-valued digit set is defined as a sequence of n successive integers m, m+1, ..., m+n-1, with m an integer (positive, negative, or zero) and n an integer greater than 1. The digit set is normalized if m=0. The digit set is symmetric if n is odd and $m = -\frac{n-1}{2}$. It follows that for any element x of a symmetric digit set, -x is also an element of the digit set. For a number in conventional form, the digit set associated with each digital position is normalized with n=r, the radix. If $n > r$, the digit set is redundant.

A carry-save adder (or borrow-save subtracter) necessarily requires that the digit set of the sum (or difference) be redundant; otherwise, the representation of the sum (or difference) is unique, which implies that each digit is in general a function of all digits of lesser significance. Only digit sets of minimum redundancy (n=r+1) for the binary case (r=2) are discussed here. Under these restrictions the first stage of design, specified in terms of normalized digit sets, leads to only one possible specification.

In the second stage of design, the choice of the symmetric digit set for the sum (or difference) is considered as well, and leads to two additional algebraic specifications, one being an adder and the other a subtracter. Thus the second stage of design, requiring a choice of specific algebraic values, leads to three algebraic structures, as follows:

1) The normalized carry-save adder,
2) The symmetric carry-save adder, and
3) The symmetric borrow-save subtracter.

For the structures considered here, a first input is in conventional form (n=r=2), the second input is in minimally redundant form (n=r+1=3), and the output (sum or difference) is also in minimally redundant form. Before the third stage (logical design) can proceed, it is necessary to specify precisely how the minimally redundant digits are represented in terms of two binary digits; that is, a binary format is chosen for the redundant digit sets. It is also required that the same format be chosen for the redundant output and the redundant input, since commonly the output of one calculation becomes the input for the next, as in, for example, recursive steps of a multiplication.

Under these conditions, seventy-two formats, or logical designs, are possible for each of the three algebraic structures. Formats of the same PN type, however, are considered equivalent, since permutation is equivalent to interchanging names of the two binary digits employed, and negation of a format digit is equivalent to replacing it by its complement wherever it appears in the design equations. There are then only nine PN types of logical designs for each of the three structures. For brevity, the nine PN types of designs will be described here only for the third algebraic structure, the symmetric borrow-save subtracter.

3. CHOICE OF NORMALIZED DIGIT SETS

The usual procedure for normalized digit set design is one of specifying the output and input digit sets, and then determining a structure meeting these specifications.

Figure 1 shows a structure consisting of two addition tables, or levels, (each shown by a box) which meets the specifications of the minimally redundant carry-save adder considered here. It is possible to show, for the given specifications, that two levels are necessary and sufficient, and that the digit sets must be chosen with the number of values of Figure 1. The following trivial observations are necessary:

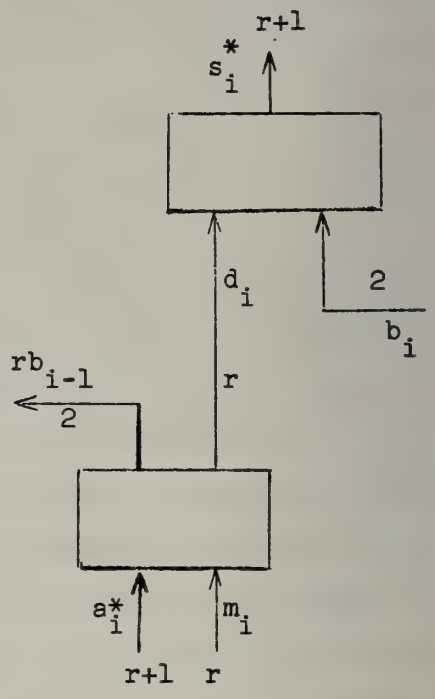

Figure 1.

1) For any addition table, the number of values of the sum digit set is one less than the sum of the numbers of values of the addend and augend digit sets.

2) The transfer input set labelled b_i has the two normalized values 0, 1; the transfer output set rb_{i-1} has the values obtained by multiplying those of b_i by the radix r; namely 0, r.

3) The composite digit set representative of the output (sum) of the lower addition table is $rb_{i-1} + d_i$. If this digit set is to consist of successive integers, the digit set for d_i must have at least r values.

4) The composite digit set $rb_{i-1} + d_i$ will have a number of values which is at most the product of the numbers of values of rb_{i-1} and of d_i. The maximum number of values is achieved only if the number of values of d_i is precisely r; if the digit set of d_i is redundant, the composite set will have fewer values than the product of those of rb_{i-1} and d_i.

The first observation implies that the sum of the numbers of values of the digit sets of d_i and b_i is r + 2. Since no digit set has less than two values, b_i must have at least two values. The third observation indicates that d_i must have at least r values, hence the choices shown for d_i and b_i are the only ones possible.

Since the values of d_i and b_i are not compatible with the specifications for the addend and augend of the carry-save adder, another addition table is necessary. From observation 4, the number of values of the output digit set is 2r, hence the two inputs will have a total number of values equal to 2r + 1. This then permits one input of r values, and a second input of r + 1 values, consistent with the desired specifications.

4. EXTENSION TO SYMMETRIC DIGIT SETS

Since each normalized digit set has zero as its least value, all digit sets appearing on Figure 1 are normalized, and hence completely specified as indicated in line 1 of Table 1. If the digit sets of s_i^* and a_i^* are symmetric, however, two solutions are possible, as shown in lines 2 and 3 of Table 1 ($\bar{1}$ represents -1).

	s_i^*	b_i	d_i	rb_{i-1}	m_i	a_i^*
normalized adder	0,1,2	0,1	0,1	0,2	0,1	0,1,2
symmetric adder	$\bar{1}$,0,1	0,1	$\bar{1}$,0	0,2	0,1	$\bar{1}$,0,1
symmetric subtracter	$\bar{1}$,0,1	$\bar{1}$,0	0,1	$\bar{2}$,0	$\bar{1}$,0	$\bar{1}$,0,1

Table 1. Values of Digit Sets for Three Algebraic Structures.

In Table 1, values for the digit sets must be chosen so that the equations $s_i^* = b_i + d_i$ and $rb_{i-1} + d_i = m_i + a_i^*$ are always satisfied. A structure is called an adder if the transfer digit b_i and the addend digit m_i are both positive; if both are negative the structure is called a subtracter, with m_i a digit of the subtrahend.

5. CHOICE OF BINARY FORMATS FOR s_i^* AND a_i^*

The first step in logical design is the choice of binary state assignments to be considered. This is a tedious but straightforward process, which may proceed as follows:

1) List the 24 ways of assigning the four states of two binary digits to four digital values, with the fourth value as yet unspecified.
2) For each of three groups, list the eight state assignments equivalent under permutation and negation. Choose one assignment from each group.
3) For each of the three state assignments resulting from step 2, list four sets of digital values by assigning to the previously unspecified fourth digital value the values 1, 0, $\bar{1}$, and "don't care".
4) Among the twelve assignments resulting from step 3, identify the three pairs equivalent under permutation and negation, and delete one of each pair. The equivalence results from the fact that the same digital value is assigned to two states during step 3. These two states can then be interchanged and the assignment will then be equivalent to another of the twelve assignments of step 3.

The procedure outlined above results in nine assignments, none of which are equivalent under permutation and negation. One such set of nine assignments for the digital values $\bar{1}$, 0, and 1 is given in Table 2. The assignments are numbered in Table 2 for future reference.

State	Digital Values								
0 0	0	0	0	0	D.C.	0	0	1	$\bar{1}$
0 1	1	1	1	1	1	1	1	1	1
1 0	$\bar{1}$	D.C.	0	$\bar{1}$	0	1	$\bar{1}$	0	0
1 1	0	$\bar{1}$	$\bar{1}$	D.C.	$\bar{1}$	$\bar{1}$	$\bar{1}$	$\bar{1}$	$\bar{1}$
Design Number	1	2	3	4	5	6	7	8	9

Table 2. Assignments of Digital Values to Four States.

For the logical designs to follow, the two binary digits which represent a_i^* will be called α_i and a_i; those which represent s_i^* will be called σ_i and s_i. For reasons given before, a_i^* and s_i^* are always consistently represented.

Simplified Boolean equations for the detailed logical designs for each of the nine assignments are given below.

Design Number	Lower Addition Table	Upper Addition Table
1	$b_{i-1} = \bar{a}_i m_i \vee \bar{a}_i \alpha_i \vee \alpha_i m_i$ $d_i = \alpha_i \oplus a_i \oplus m_i$	$\sigma_i = b_i$ $s_i = d_i$ or $\sigma_i = \bar{d}_i$ $s_i = \bar{b}_i$
2	$b_{i-1} = \alpha_i \vee \bar{a}_i m_i$ $d_i = a_i \oplus m_i$	$\sigma_i = b_i \bar{d}_i$ $s_i = b_i \oplus d_i$
3	$b_{i-1} = \alpha_i a_i \vee \bar{a}_i m_i$ $d_i = a_i \oplus m_i$	$\sigma_i = b_i$ or $\sigma_i = \bar{d}_i$ $s_i = b_i \oplus d_i$
4	$b_{i-1} = \alpha_i \vee \bar{a}_i m_i$ $d_i = m_i \oplus (\alpha_i \vee a_i)$	$\sigma_i = b_i \bar{d}_i$ $s_i = \bar{b}_i d_i$
5	$b_{i-1} = \alpha_i (a_i \vee m_i)$ $d_i = a_i \oplus m_i$	$\sigma_i = b_i \vee \bar{d}_i$ $s_i = b_i \oplus d_i$
6	$b_{i-1} = \alpha_i a_i \vee \bar{\alpha}_i \bar{a}_i m_i$ $d_i = m_i \oplus (\alpha_i \vee a_i)$	$\sigma_i = b_i \bar{d}_i$ $s_i = b_i \oplus d_i$ or $\sigma_i = b_i \oplus d_i$ $s_i = b_i \bar{d}_i$
7	$b_{i-1} = \alpha_i \vee \bar{a}_i m_i$ $d_i = m_i \oplus (\alpha_i \vee a_i)$	$\sigma_i = b_i \bar{d}_i$ $s_i = \bar{b}_i d_i$
8	$b_{i-1} = \alpha_i (a_i \vee m_i)$ $d_i = m_i \oplus (\bar{\alpha}_i \vee a_i)$	$\sigma_i = b_i \vee \bar{d}_i$ $s_i = b_i \bar{d}_i$
9	$b_{i-1} = \alpha_i a_i \vee a_i m_i \vee \bar{\alpha}_i \bar{a}_i$ $d_i = m_i \oplus (\bar{\alpha}_i \vee a_i)$	$\sigma_i = b_i \vee \bar{d}_i$ $s_i = b_i \oplus d_i$ or $\sigma_i = \overline{b_i \oplus d_i}$ $s_i = \bar{b}_i d_i$

Table 3. Boolean Equations for Symmetric Borrow-Save Subtracters.

The combined equations for design 1 can be written as

$$s_i = \alpha_i \oplus a_i \oplus m_i$$

$$\sigma_{i-1} = \bar{a}_i m_i \vee \bar{a}_i \alpha_i \vee \alpha_i m_i \ .$$

Design 1 is therefore identical with the long-known stored borrow subtracter of Equations (3). The state assignment for design 1 is equivalent to giving α_i a weight of -1 and a_i a weight of +1 (Table 2). Correspondingly σ_{i-1} has weight -2 and s_i has weight +1, so that

$$-2\sigma_{i-1} + s_i = a_i - m_i - \alpha_i \ ,$$

which is equivalent to Equation (2) interpreted for the stored-borrow modification.

The combined equations for design 2 can be written as

$$s_i = a_i \oplus m_i \oplus (\alpha_{i+1} \vee \bar{a}_{i+1}\, m_{i+1})$$

$$\sigma_i = (\overline{a_i \oplus m_i})(\alpha_{i+1} \vee \bar{a}_{i+1}\, m_{i+1})$$

indicating that design 2 is identical with the long-known stored-borrow subtracter of Equations (6). The state assignment for design 2 is equivalent to giving α_i and σ_i weights of -2, and a_i and s_i weights of +1, with the value -2 excluded (corresponding to $\sigma_i = 1$, $s_i = 0$).

Designs 4 and 7, which are identical, are minor variations of design 2. In these designs, $b_i \oplus d_i = \sigma_i \vee s_i$, whereas in design 2, $b_i \oplus d_i = s_i$. In effect the OR operation needed to complete the EXCLUSIVE OR in the upper addition table is supplied in the formation of d_i in the lower addition table. Design 8, if a_i and s_i are complemented, becomes the Boolean dual of designs 4 and 7. Design 5 is equivalent, under negation of a_i, to the Boolean dual of design 2.

Designs 6 and 9 appear too complicated to warrant further discussion.

Design 3 is believed to be new. The state assignment for design 3 is equivalent to α_i and a_i being, respectively, the sign and magnitude of a_i^*. This design is therefore referred to as the stored sign subtracter.

7. FURTHER DESIGN CONSIDERATIONS

Frequently when stored-borrow subtracters are employed, separate circuitry is provided for conversion, or assimilation, of the redundantly represented digits to conventional form. In Figure 1 for a binary subtracter, the lower addition table can be used for assimilation with a_i^* the digit to be assimilated, m_i the incoming propagating borrow, rb_{i-1} the outgoing propagating borrow, and d_i the assimilated digit. Thus, the complexity of the assimilation circuitry is indicated by the design equations for the lower addition table in Table 3. The relative difficulty of assimilation for design 1, discussed earlier, is clearly apparent. Designs 2 and 5 are the simplest, with designs 3, 4, 7, and 8 only slightly more complex.

Although conversion of a subtracter into an adder is usually performed by complementation of each digit m_i, with borrow insertion in the least significant digit, an alternative approach is advantageous in some circumstances. Let s, a, and m be the numbers represented by all digits s_i^*, a_i^*, and m_i, respectively. If the values of s_i^* and a_i^* are symmetric, then -s and -a can be formed by replacing s_i^* by $-s_i^*$ and a_i^* by $-a_i^*$ in each digital position. Since $s = a - m$, the result of these negations is $-s = -(-a - m) = a + m$, that is, an addition is performed. This approach has potential advantages in some variable field length operations, since it does not require any special operations on the least significant digit. The stored sign subtracter of design 3 is simplest for this operation, since negation of each digit requires only the complementation of its sign digit.

An advantage of the deterministic procedure described is that statistical calculations can be made at the first stage of design, and, if interpreted properly, apply to all descendents of that design. For example, the probability of the center digit (1 for the normalized digit set; 0 for the symmetric digit set) of the sum digit set s_i^* is always $\frac{1}{2}$ if the two values of m_i are equally likely, independent of the probabilities of the value of a_i^*.

8. SUMMARY AND CONCLUSIONS

A deterministic procedure has been described which begins with a single normalized digit set structure for a carry-save adder which leads to three algebraic structures. Each of these three result in nine logical designs, one group of which has been described. Of the nine, two have been known for many years, four are minor variations of these, two are new but appear impractical, and one is new and appears to be of potential value for some variable field length systems.

The digit set approach has been employed[1] for the study of more complicated binary structures, including three level adders in which both addend and augend are three-valued, and for the study of higher radix structures. The carry-save adder described here is simple and unusually tractable in comparison.

BIBLIOGRAPHY

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ACKNOWLEDGMENT

The use of transformations from normalized digit sets and the development of systematic procedures for finding limited carry propagation adders subject to specified operand and sum digit sets is based on the work of Dr. Fred Rohatsch. The author is grateful to Dr. Rohatsch for many productive discussions on the subject matter of this paper.

5.6 Symbol Manipulation Language EOL

During the last quarter, the following steps of the EOL project were prepared.

1) File Number 734 describing language X1 was written.

2) The description of the EOL interpreter in language X1 was finished.

3) The EOL interpreter was written in IBM 7094 code and check out begun.

4) The EOL report was written.

5) A first version of the EOL compiler was written in EOL but not yet checked out.

6) File Number 733, "Outline of EOL Language" was written.

(L. Lukaszewicz, J. Nievergelt,
F. Fisher, D. Edgar, R. Sanders)

5.7 Translator Writing Systems

During the last month of the quarter a survey was made of parsing algorithms for languages which have context free (CF) grammars, with a view to automating the generation of the syntactic information required to analyze and recognize a source program string. Algorithms based on precedence tables (which have certainly been produced automatically) and Floyd's productions (effectively reductions) are in common use. The precedence method has disadvantages due to table size, and the frequent occurrence of precedence ambiguities which force the language designer to modify the grammar, and no automatic generator of Floyd productions which will handle languages like Algol exists.

BNF is, in general, a relatively terse method of specifying the syntax of a CF language to a user, yet it must be broken down even further before it is in a form suitable for driving a syntax recognizer of the language. It would be useful to be able to specify the syntax of a language in the most macroscopic form possible, i.e., at a higher level than that of BNF, and provide a translator which would convert this syntax directly into Floyd productions, possibly using precedence functions to assist in the process.

The translator would, if possible, fix up any ambiguities which might be inherent in the syntax. The adequate specification of semantics at such a high level may create difficulties, but these could be overcome by dropping to a lower level of syntax definition when required.

Specifying language syntax in a more macroscopic form should greatly improve the readability of the specification to a potential user of the language. Provision of a syntax translator as proposed above should free the language designer of many of his worries, or at least give him diagnostic information on his language design more quickly.

Further to the task of writing translators it is proposed to extend the efforts (notably by Feldman) which have been devoted to the specification of the semantics associated with languages.

(R. S. Northcote)

Purpose of Work

For dilute gases, the pair distribution function $n_{12}(\underset{\sim}{R}_1,\underset{\sim}{R}_2)$ can be expanded in a power series in the number density n. The result is

$$n_{12}(\underset{\sim}{R}_1,\underset{\sim}{R}_2) = n^2(1 + ng)\, W_2(\underset{\sim}{R}_1,\underset{\sim}{R}_2) + \text{higher order terms in n}$$

where $W_2(R_1,R_2)$ is the two particle Slater sum

$$W_2(\underset{\sim}{R}_1,\underset{\sim}{R}_2) = \frac{1}{2!\lambda^6} \sum_i \Psi_i^*(\underset{\sim}{R}_1,\underset{\sim}{R}_2)\, e^{-\beta H}\, \Psi_i(\underset{\sim}{R}_1,\underset{\sim}{R}_2)$$

and $\lambda = (2\pi\hbar^2\beta/M)^{\frac{1}{2}}$

$$\beta = \frac{1}{kT}$$

The term

$$g(\underset{\sim}{R}_1,\underset{\sim}{R}_2) = \frac{1}{W_2(\underset{\sim}{R}_1,\underset{\sim}{R}_2)} \int d^3R_3 \left[W_3(\underset{\sim}{R}_1,\underset{\sim}{R}_2,\underset{\sim}{R}_3) - W_2(\underset{\sim}{R}_1,\underset{\sim}{R}_2)\, W_2(\underset{\sim}{R}_1,\underset{\sim}{R}_3) - W_2(\underset{\sim}{R}_1,\underset{\sim}{R}_2)\, W_2(\underset{\sim}{R}_2,\underset{\sim}{R}_3) - W_2(\underset{\sim}{R}_1,\underset{\sim}{R}_2)\right] \tag{1.1}$$

has been calculated by Harry Jordan. The purpose of this work is to calculate $g(R_1,R_2)$ making the approximation:

$$W_3(\underset{\sim}{R}_1,\underset{\sim}{R}_2,\underset{\sim}{R}_3) \tilde{=} W_2(\underset{\sim}{R}_1,\underset{\sim}{R}_2)\, W_2(\underset{\sim}{R}_1,\underset{\sim}{R}_3)\, W_2(\underset{\sim}{R}_2,\underset{\sim}{R}_3) \quad . \tag{1.2}$$

substituting (1.2) into (1.1) we obtain,

$$g(\underset{\sim}{R}_1,\underset{\sim}{R}_2) = \int d^3R_3 \left(W_2(\underset{\sim}{R}_1,\underset{\sim}{R}_3)-1\right)\left(W_2(\underset{\sim}{R}_2,\underset{\sim}{R}_3)-1\right) \quad . \tag{1.3}$$

Assuming the volume of the gas to be infinite,

$$W_2(\underset{\sim}{R}_1,\underset{\sim}{R}_3) \longrightarrow W_2(|\underset{\sim}{R}_1-\underset{\sim}{R}_3|)$$

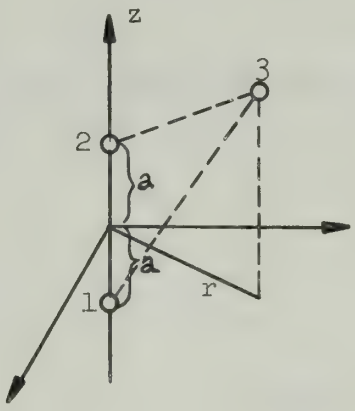
the integrals (1.3) can be further reduced by expressing it in cylindrical coordinates:

From the figure:

$$|\underset{\sim}{R}_1-\underset{\sim}{R}_3| = \sqrt{r^2 + (z+a)^2} \equiv R_+$$

$$|\underset{\sim}{R}_2-\underset{\sim}{R}_3| = \sqrt{r^2 + (z-a)^2} \equiv R_-$$

$$|\underset{\sim}{R}_1-\underset{\sim}{R}_2| \equiv R_{12} = 2a$$



We have azimuthal symmetry and φ can be integrated out. Further, the integrand is invariant under reflection: $z \to -z$ so,

$$g(R_{12}) = 4\pi \int_0^\infty \int_0^\infty r\,dr\,dz \left(W_2(R_+)-1\right)\left(W_2(R_-)-1\right)$$

$$g(R_{12}) = g(2a) = 2\pi \int_0^\infty \int_0^\infty dr^2\,dz \left(W_2(R_+)-1\right)\left(W_2(R_-)-1\right) \qquad (1.4)$$

Description of the program

The function $W_2(R)$ has been calculated and is provided in tabular form for discrete values of R in units of $\sqrt{2}\,\lambda \equiv \frac{\lambda}{\sqrt{\pi}}$. The program reads this table in along with the temperature and particle spacing (in units of $\sigma = 2.56$ Å) as DATA. A finite Riemann sum is formed. Values of $W_2(R)$ are computed from the table with three point interpolation. When R is out of the range of the table, $W_2(R)$ is calculated from the Wigner-Kirkwood expansion. The resulting integral is printed and punched out in units of λ^{-3}.

The Integration Method

The integral

$$g(2a) = 2\pi \int_0^\infty \int_0^\infty \left(W_2(R_+)-1\right)\left(W_2(R_-)-1\right)\, dr^2 dz$$

$$\equiv \int_0^\infty \int_0^\infty F(\xi,z)\, d\xi dz \quad \xi = r^2$$

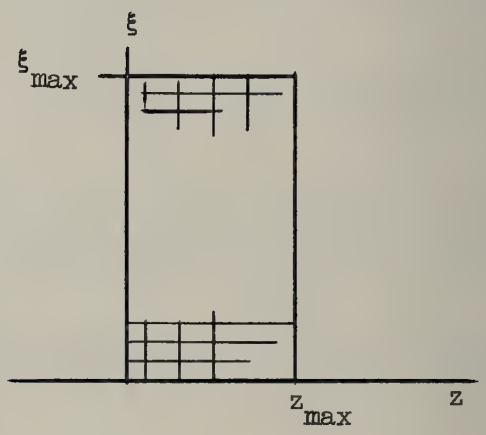
is approximated by summing over a grid with spacing

$$\Delta\xi = c = \text{const.} \quad , \quad \Delta z = d = \text{const.}$$

i.e.

$$\int_0^\infty \int_0^\infty F(\xi,z)\, d\xi dz$$

$$\tilde{-}\ cd \sum_{i=1}^{M} \sum_{j=1}^{M} F(\bar{\xi}_i, \bar{z}_j)$$



where

$$\bar{\xi}_i = (i - \tfrac{1}{2})c$$

$$\bar{z}_j = (j - \tfrac{1}{2})d$$

i.e. the function is evaluated at the center of the squares of the grid. The sum is carried up to a maximum number, M where

$$\bar{\xi}_{MAX} = (M - \tfrac{1}{2})c \tilde{-} Mc$$

$$\bar{z}_{MAX} = (M - \tfrac{1}{2})d \tilde{-} Md$$

which is sufficiently large so that the truncation error corresponding to the integral over the rest of the space is small. For simplicity, we take $\xi_{MAX} = z^2_{MAX}$ so that $Mc \simeq M^2d^2$. Hence $c = Md^2$ so our integral finally becomes

$$g(2a) \simeq 2\pi\, Md^3 \sum_{i=1}^{M} \sum_{j=1}^{M} \left[W_2(R^+_{ij})-1\right]\left[W_2(R^-_{ij})-1\right] \tag{1.5}$$

where

$$R^{\pm}_{ij} = \sqrt{(i - \tfrac{1}{2})\, Md^2 + \left[(j - \tfrac{1}{2})d \pm a\right]^2} \tag{1.6}$$

Determination of Upper Limit of Sum, M

The sum is truncated when R is large enough that $W_2(R)$ can be approximated by $e^{-\gamma(\frac{\rho}{R})^6}$ in which case all other terms in the Wigner-Kirkwood expansion are negligible. The criterion is that the ratio of all terms to the $(\frac{\rho}{R})^6 \equiv x^6$ term be 10^{-2}.

The significant terms are:

$$\frac{x^8 \text{ term}}{x^6 \text{ term}} = \frac{2.5\,\frac{\gamma}{2}\left(\frac{\rho}{R}\right)^8}{\gamma\left(\frac{\rho}{R}\right)^6} = \frac{2.5}{\rho^2}\left(\frac{\rho}{R}\right)^2 = 10^{-2}$$

$$R_{MAX} = 10\sqrt{2.5} \simeq 16 \tag{2.1}$$

$$\frac{x^{12} \text{ term}}{x^6 \text{ term}} = \frac{(\rho/R)^{12}}{(\rho/R)^6} = 10^{-2}$$

$$R_{MAX} = \rho\, 10^{\frac{1}{3}} \simeq 2.2\rho \tag{2.2}$$

Now, from (1.6)

$$R_{max} \tilde{=} Md$$

so in case

(2.1): $Md \tilde{=} 16 \qquad M \tilde{=} \frac{16}{d}$

(2.2): $Md \tilde{=} 2.2\rho \qquad M \tilde{=} \frac{2.2\rho}{d}$

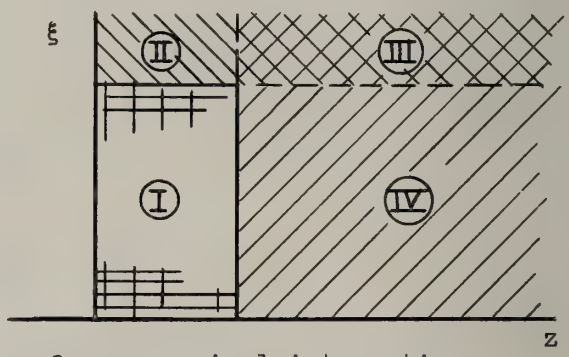
For low temperatures $2.2\rho < 16$, but for $T \sim 273^{\circ}K$ $2.2\rho > 16$ so we take

$$M = \text{integer part} \left[\max \left\{ \frac{16}{d} , \frac{2.2\rho}{d} \right\} \right]$$

Truncation Error

The truncation error is due to the fact that we are unable to perform an infinite sum on the computer but must truncate our summation at $i = j = M$. We may obtain a reasonable upper bound on the truncation error (which is abbreviated Res. for residue) in the following way:

Consider the regions I, II, III, IV, which divide up the infinite space of positive ξ, z.



Region I is the region over which we perform numerical integration. Regions II, III, and IV are infinite regions in which

$$W_2(R) \tilde{=} e^{-\gamma(\rho/R)^6}$$

The residue is equal to the integral of $2\pi \left(W_2(R_+)-1)(W_2(R_-)-1 \right)$ over regions II, III, and IV.

$$\text{Res} < 2\pi \int_0^\infty \int_{z_m}^\infty \left(e^{-\gamma \left(\frac{\rho}{R_+}\right)^6} - 1\right)\left(e^{-\gamma \left(\frac{\rho}{R_-}\right)^6} - 1\right) d\xi\, dz$$

$$+ 2\pi \int_{\xi_m}^\infty \int_0^\infty \left(e^{-\gamma \left(\frac{\rho}{R_+}\right)^6} - 1\right)\left(e^{-\gamma \left(\frac{\rho}{R_-}\right)^6} - 1\right) d\xi\, dz$$

The two integrals overlap in region III, hence the strict inequality. Making use of the fact that $\frac{\rho}{R_\pm} \ll 1$ we expand the exponentials, obtaining

$$\text{Res} < 2\pi \int_0^\infty \int_{z_m}^\infty \gamma^2 \frac{\rho^{12}}{R_+^6 R_-^6} d\xi\, dz + 2\pi \int_{\xi_m}^\infty \int_0^\infty \gamma^2 \frac{\rho^{12}}{R_+^6 R_-^6} d\xi\, dz$$

Now, $\frac{1}{R_-} > \frac{1}{R_+}$ so

$$\text{Res} < 2\pi \int_0^\infty \int_{z_m}^\infty \gamma^2 \left(\frac{\rho}{R_-}\right)^{12} d\xi\, dz + 2\pi \int_{\xi_m}^\infty \int_0^\infty \gamma^2 \left(\frac{\rho}{R_-}\right)^{12} d\xi\, dz$$

Consider the first integral (over regions III and IV)

$$I_1 \equiv 2\pi \gamma^2 \rho^{12} \int_0^\infty \int_{z_m}^\infty \frac{d\xi\, dz}{[(z-a)^2+\xi]^6}$$

By straight forward integration we obtain

$$I_1 = \frac{2\pi \gamma^2 \rho^{12}}{45} \frac{1}{(z_m-a)^9}$$

Consider now, the second integral:

$$I_2 \equiv 2\pi\,\gamma^2\,\rho^{12} \int_{\xi_m}^{\infty}\int_{0}^{\infty} \frac{d\xi\,dz}{[(z-a)^2+\xi]^6}$$

$$= \frac{2\pi\,\gamma^2\,\rho^{12}}{5} \int_{0}^{\infty} \frac{dz}{[(z-a)^2+\xi_m]^5}$$

Let $z-a = \sqrt{\xi_m}\tan\theta \qquad -\frac{\pi}{2} \le \theta \le \frac{\pi}{2}$

$$I_2 = \frac{2\pi\,\gamma^2\,\rho^{12}}{5\sqrt{\xi_m^9}} \int_{-\tan^{-1}\frac{a}{\sqrt{\xi_m}}}^{\pi/2} \cos^8\theta\,d\theta$$

Recall $\xi_m = r_m^2$ so

$$I_2 = \frac{2\pi\,\gamma^2\,\rho^{12}}{5r_m^9} \int_{-\tan^{-1}\frac{a}{r_m}}^{\pi/2} \cos^8\theta\,d\theta$$

By repeated use of the relation,

$$\int \cos^n\theta\,d\theta = \frac{1}{n}\cos^{n-1}\theta\,\sin\theta + \frac{n-1}{n}\int \cos^{n-2}\theta\,d\theta$$

we have

$$\int \cos^8\theta\,d\theta$$

$$= \frac{1}{8}\left[\cos^7\theta\sin\theta + 7\left[\frac{1}{6}\cos^5\theta\sin\theta + \frac{5}{6}\left[\frac{1}{4}\cos^3\theta\sin\theta + \frac{3}{4}\left[\frac{\theta}{2} + \frac{\sin\theta\cos\theta}{2}\right]\right]\right]\right]$$

$$= \frac{7!!}{8!!}(\cos\theta\,\sin\theta + \theta) + \frac{7\cdot 5}{8\cdot 6\cdot 4}\cos^3\theta\sin\theta + \frac{7}{8\cdot 6}\cos^5\sin\theta + \frac{1}{8}\cos^7\theta\sin\theta$$

Hence,

$$I_2 = \frac{2\pi\,\gamma\,\rho^{12}}{5r_m^9}\left\{\frac{7!!}{8!!}\left(\frac{\pi}{2} - \cos^{-1}\sqrt{X}\right) + \frac{a}{r_m}\left[\frac{7!!}{8!!}X + \frac{7\cdot5}{8\cdot6\cdot4}X^2 + \frac{7}{8\cdot6}X^3 + \frac{1}{8}X^4\right]\right\}$$

where $X \equiv \dfrac{1}{1+\left(\frac{a}{r_m}\right)^2} \longrightarrow 1$ as $\left(\frac{a}{r}\right)^2 \longrightarrow 0$

Furthermore, $X \leq 1$

We let $X \to 1$.

$$I_2 \lesssim \frac{2\pi\,\gamma^2\,\rho^{12}}{5r_m^9}\left\{.429 + \frac{a}{r_m}\left[.273 + .182 + .146 + .125\right]\right\}$$

Then,

$$\text{Res} < I_1 + I_2 \lesssim \frac{2\pi\,\gamma^2\,\rho^{12}}{5}\left\{\frac{1}{9(z_m-a)^9} + \frac{.429}{r_m^9} + \frac{.726}{r_m^9}\,\frac{a}{r_m}\right\}$$

Using $z_m \tilde{-} r_m \tilde{-} Md$ we have finally:

$$\text{Res} < \frac{2\pi}{5}\gamma^2\,\rho^{12}\left\{\frac{1}{9(Md-a)^9} + \frac{1}{(Md)^9}\left[.429 + .726\,\frac{a}{Md}\right]\right\}$$

Using the criterion mentioned above for choosing M and hence z_m and r_m, the truncation error was found to be negligible for most values of a.

Details of Program

A block diagram of the main program and associated subroutines is given on pages 165, 66, 67. A glossary of the symbols used is found on page 168. A print out of the entire program is found on page 170. A brief description of the subroutines follows:

FUNCTIØN GFUNC(X)

This subroutine calculates the Slater sum $W_2(R)$ = GFUNC(R) using the Wigner-Kirkwood expansion.

SUBRØUTINE READIN

This subroutine reads in necessary data for the program. The data consist of:

(1) The temperature in degrees Kelvin.

(2) Values of the particle spacing 2a in units of σ.

(3) Values of the tabulated function $W_2(R)$ and the first two values of R (the rest are assumed to be equally spaced) where R is in units of $\sqrt{2}\,\lambda$.

SUBRØUTINE INTERP(I,J)

This program provides a value of the argument of the sum:

$$\sum_{ij} \left(W_2(R_{ij}^{+}) - 1\right)\left(W_2(R_{ij}^{-}) - 1\right)$$

First it is determined whether R_{ij}^{+} is in the range of the table of values of $W_2(R)$. If it is in the range then the appropriate value of $W_2(R)$ is calculated from the table by a three point interpolation formula. If it is below the range of the table, $W_2(R)$ is set to the first value of W in the table, which is zero. If R_{ij}^{+} is above the range of the table W_2 is calculated via the Wigner-Kirkwood expansion. Then R_{ij}^{-} is determined, and the above steps are carried out for $W_2(R_{ij}^{-})$. The result, $\left(W_2(R_{ij}^{+}) - 1\right)\left(W_2(R_{ij}^{-}) - 1\right)$, is stored in location G.

Units

The integration is performed in units of $\sqrt{2}\,\chi$ then the result is multiplied by suitable factor to convert to units of λ^3. Note that a is the half distance between atoms in units of $\sqrt{2}\,\chi$. Now introduce parameter, $\rho = \frac{\sigma}{\sqrt{2}\chi}$ $(= .5217\sqrt{T}$ for $He^4)$. Then, if R is in units of $\sqrt{2}\,\chi$ and r is a distance in the same units as σ.

$$\frac{R}{\rho} = \frac{r}{\sigma}$$

Hence if A is the distance between particles 1 and 2 in units of σ

$$\frac{a}{\rho} = \frac{1}{2} \cdot \frac{A}{1} \quad \text{or} \quad a = \frac{1}{2}\rho A$$

For R in units of $\sqrt{2}\,\chi$ the Wigner-Kirkwood expansion is expressed:

$$W_2(R) \tilde{=} \exp\left[\gamma\left(\frac{\rho}{R}\right)^6 - \gamma\left(\frac{\rho}{R}\right)^{12} + 2.5\,\frac{\gamma}{\rho^2}\left(\frac{\rho}{R}\right)^8 + 7\,\frac{\gamma}{\rho^9}\left(\frac{\rho}{R}\right)^{10} + \left(1.5\,\frac{\gamma^2}{\rho^2} - 11\,\frac{\gamma}{\rho^2}\right)\left(\frac{\rho}{R}\right)^{14}\right]$$

where $\gamma \equiv 4\alpha\beta$, $\alpha = 14.04 \times 10^{-16}$ erg , $\beta = \frac{1}{kT}$.

To convert the integral to units of λ^3 we note that

$$\chi = \frac{\lambda}{\sqrt{2\pi}} \quad \text{or} \quad \sqrt{2}\,\chi = \frac{1}{\sqrt{\pi}}\,\lambda \ .$$

Hence we must multiply the result of the integral and the residue by the factor: $\pi^{-3/2}$ i.e. $2\pi \rightarrow \frac{2}{\sqrt{\pi}}$.

Thus,

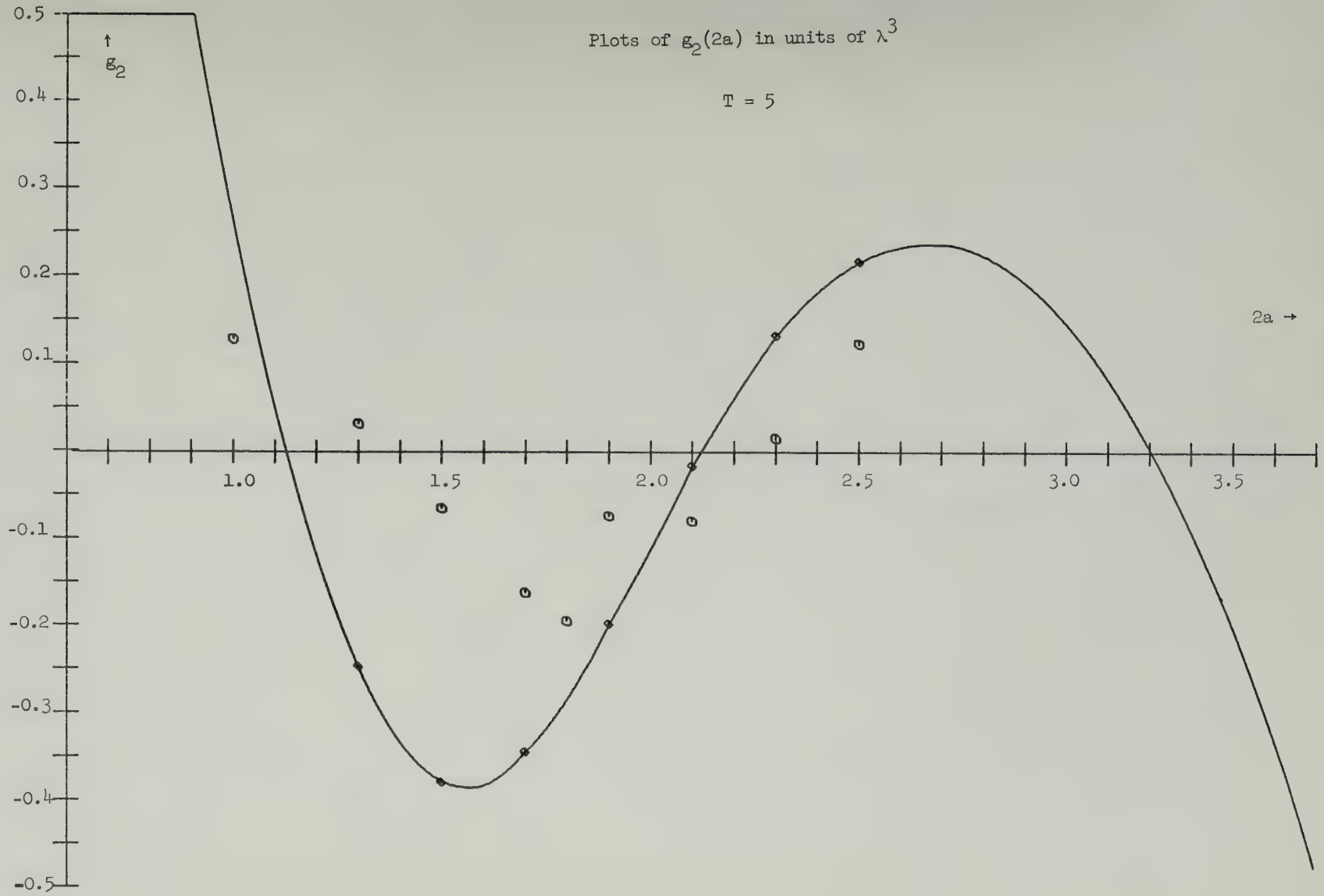
$$g(2a) = \frac{2}{\sqrt{\pi}} \, Md^3 \sum_{i=1}^{M} \sum_{j=1}^{M} \left[W_2(R_{ij}^{+}) - 1 \right] \left[W_2(R_{ij}^{-}) - 1 \right] + \text{Res}$$

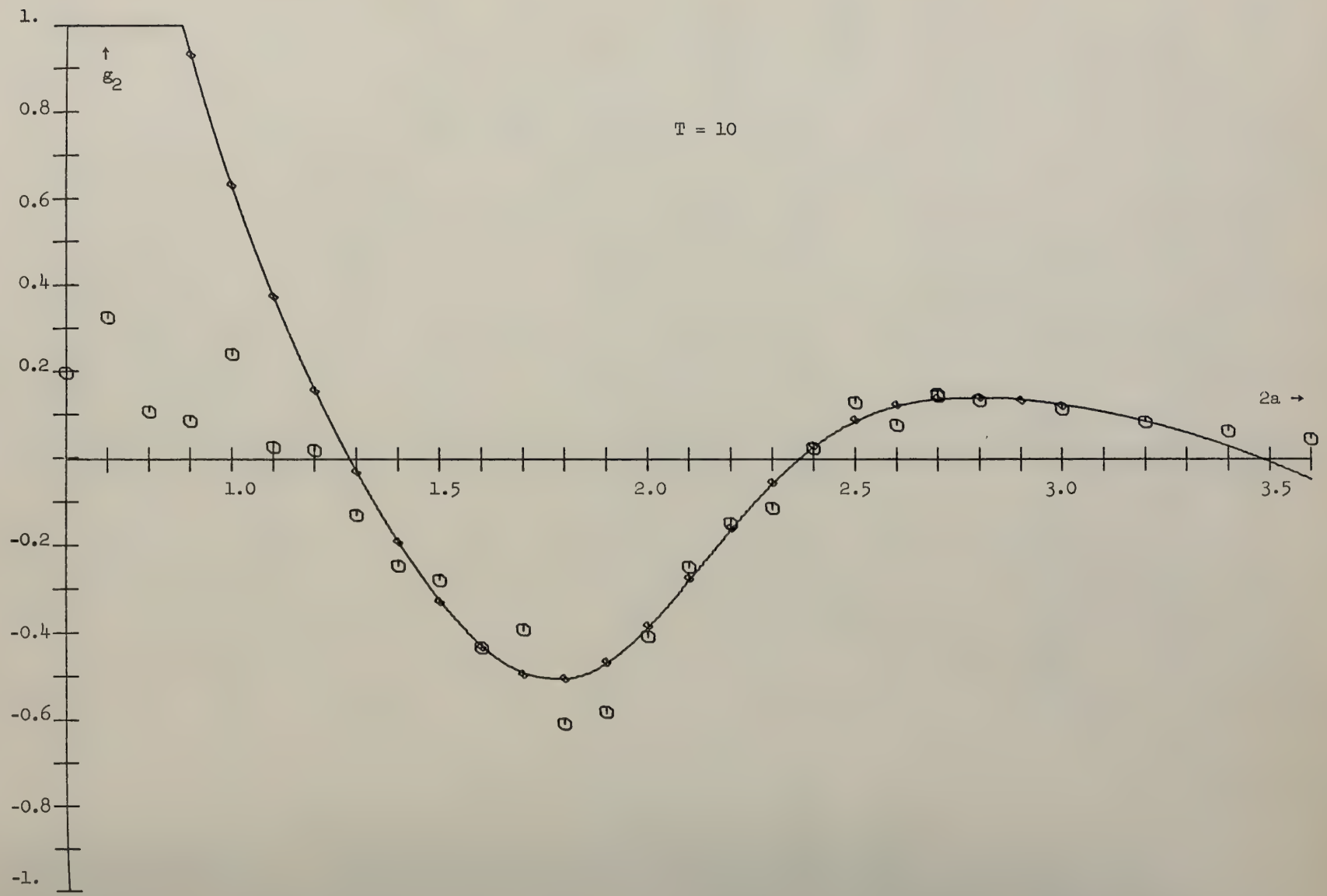
$$\text{Res} < \frac{2}{5\sqrt{\pi}} \, \gamma^2 \, \rho^{12} \left\{ \frac{1}{9(Md-a)^9} + \frac{1}{(Md)^9} \left[.429 + .726 \, \frac{a}{Md} \right] \right\}$$

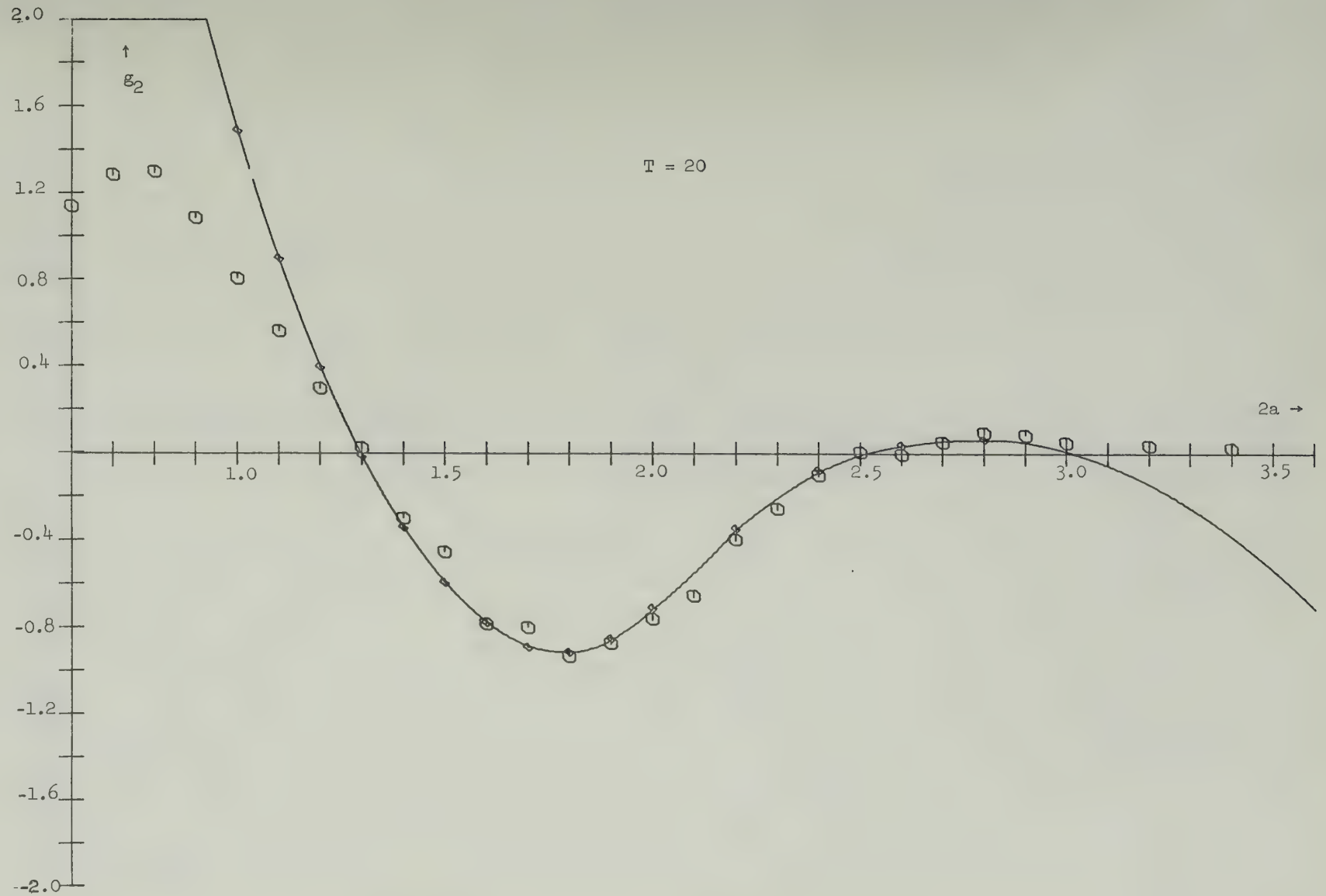
where $g(2a)$ and Res are in units of λ^3.

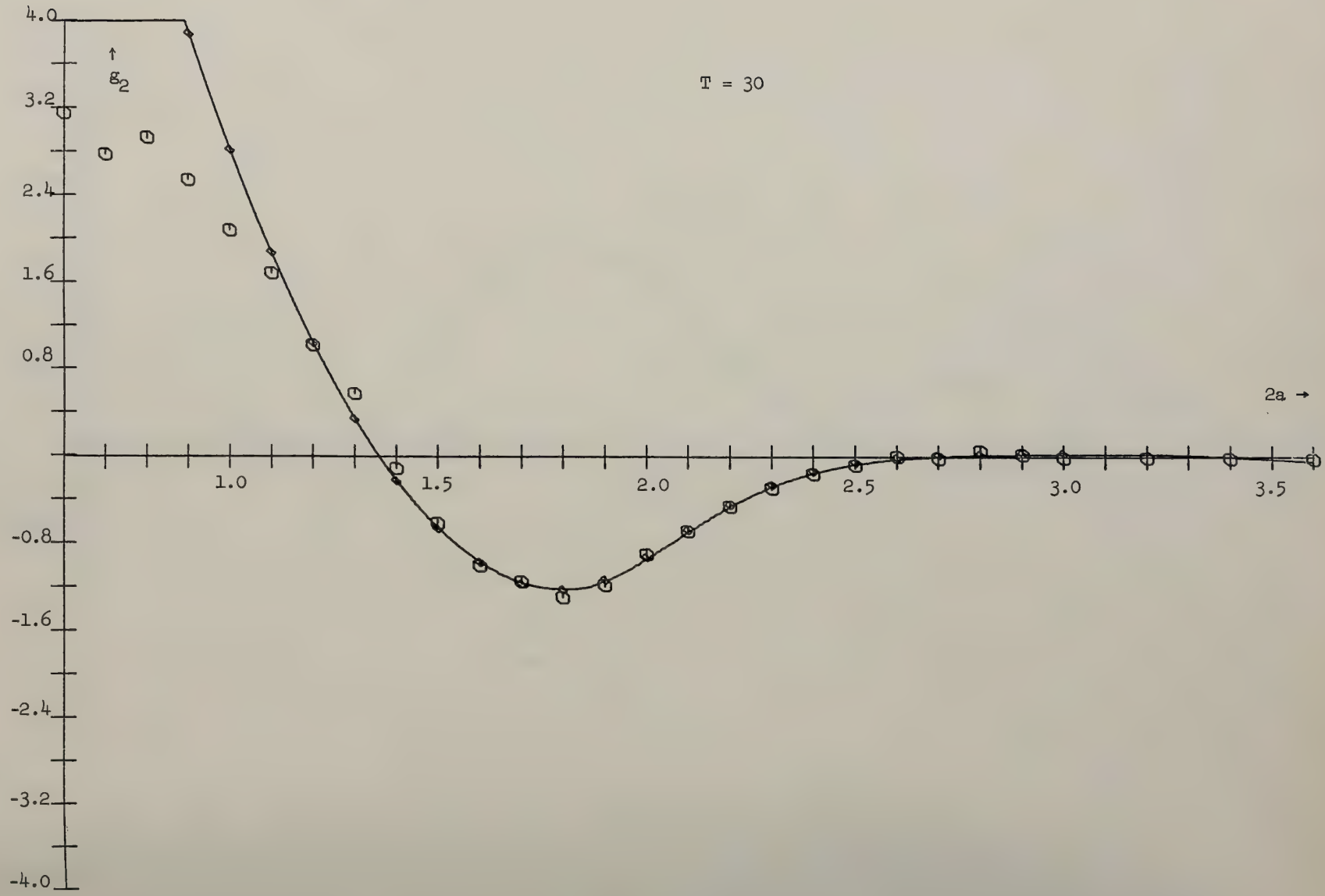
Results

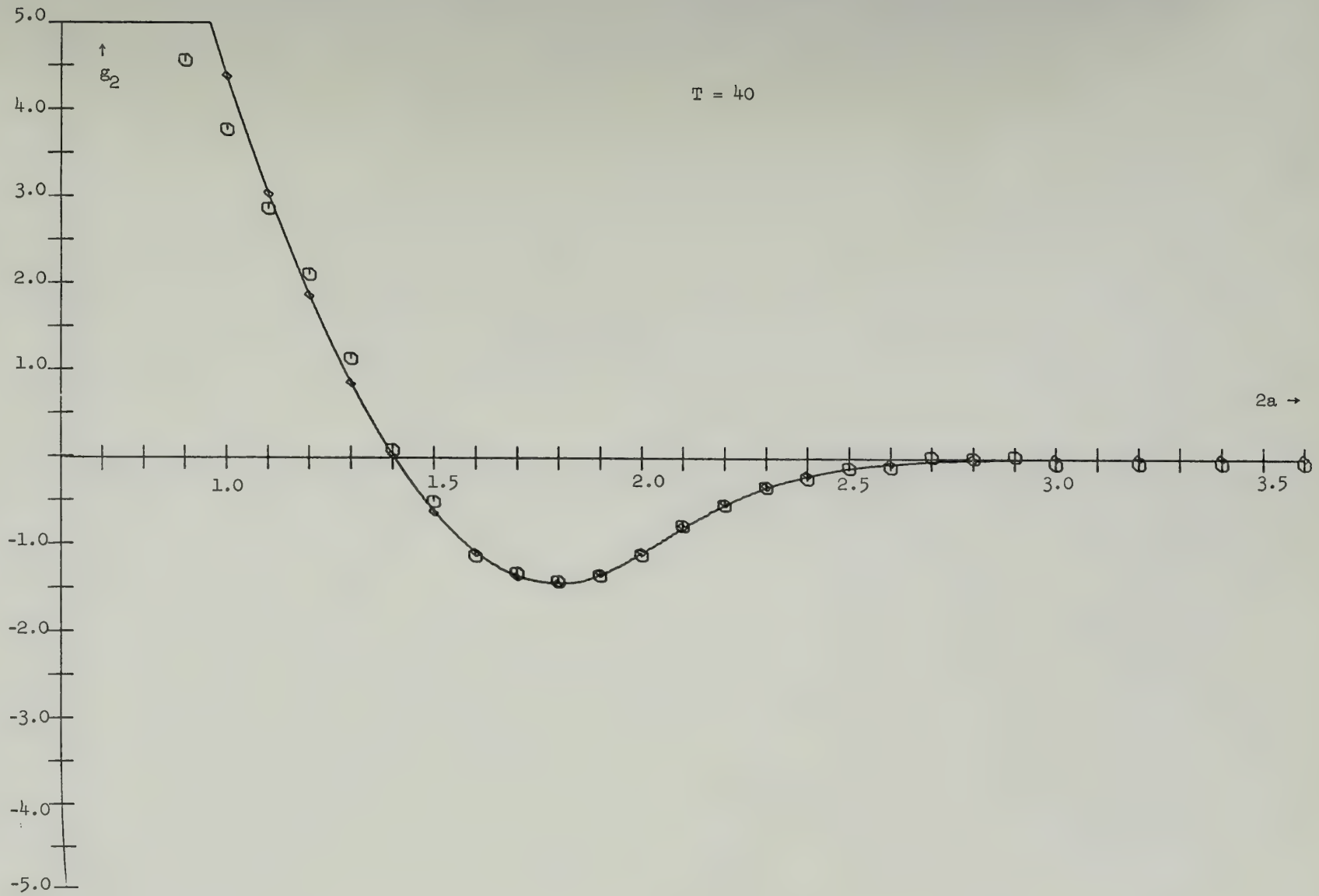
Plots of $g(2a)$ for temperatures ranging from 5 to 273°K are found on page . The results which do not use the approximation: $W_3(\underset{\sim}{R}_1\underset{\sim}{R}_2\underset{\sim}{R}_3) \tilde{-} W_2(\underset{\sim}{R}_1\underset{\sim}{R}_2) \, W_2(\underset{\sim}{R}_1\underset{\sim}{R}_3) \, W_2(\underset{\sim}{R}_1\underset{\sim}{R}_3)$ calculated by Harry Jordan are also plotted on the same graph (the large circles). It is seen that there is good agreement for larger temperatures and larger values of 2a. The pair distribution function obtained from this calculation is also plotted on page .

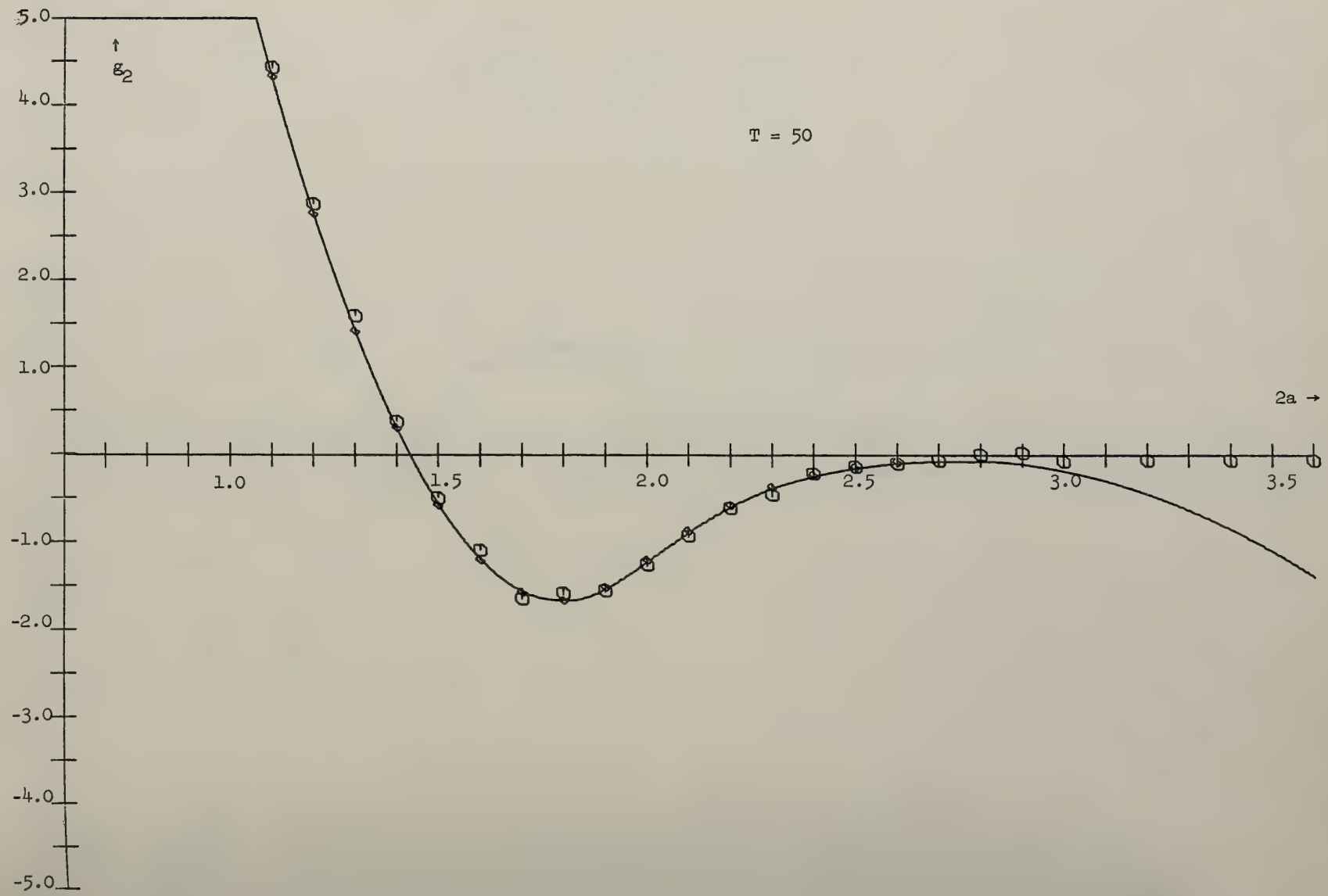

Plots of $g_2(2a)$ in units of λ^3
T = 5
g_2 ↑
2a →
0.5
0.4
0.3
0.2
0.1
-0.1
-0.2
-0.3
-0.4
-0.5
1.0
1.5
2.0
2.5
3.0
3.5

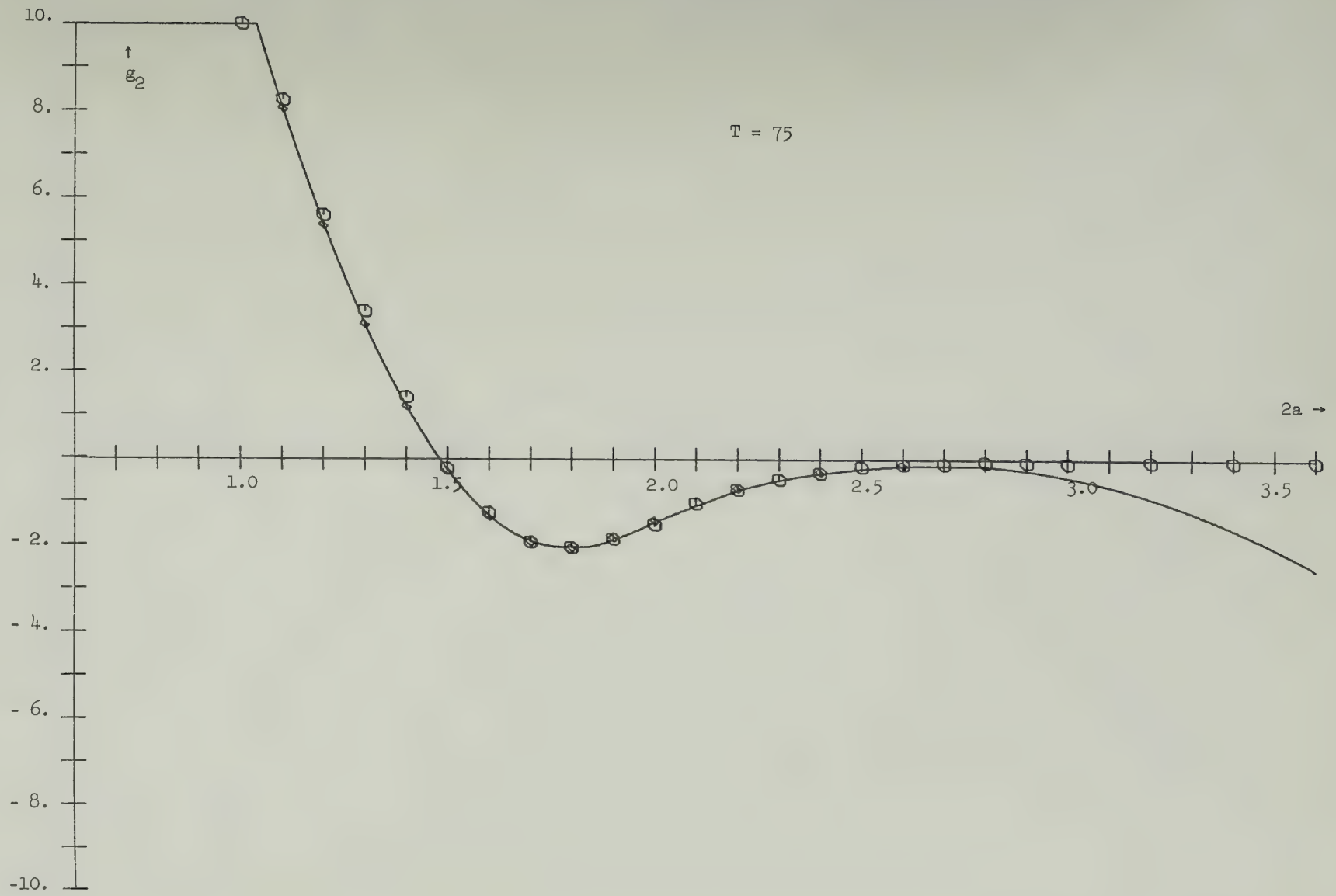

1.
0.8
0.6
0.4
0.2
-0.2
-0.4
-0.6
-0.8
-1.
g_2
T = 10
2a
1.0
1.5
2.0
2.5
3.0
3.5

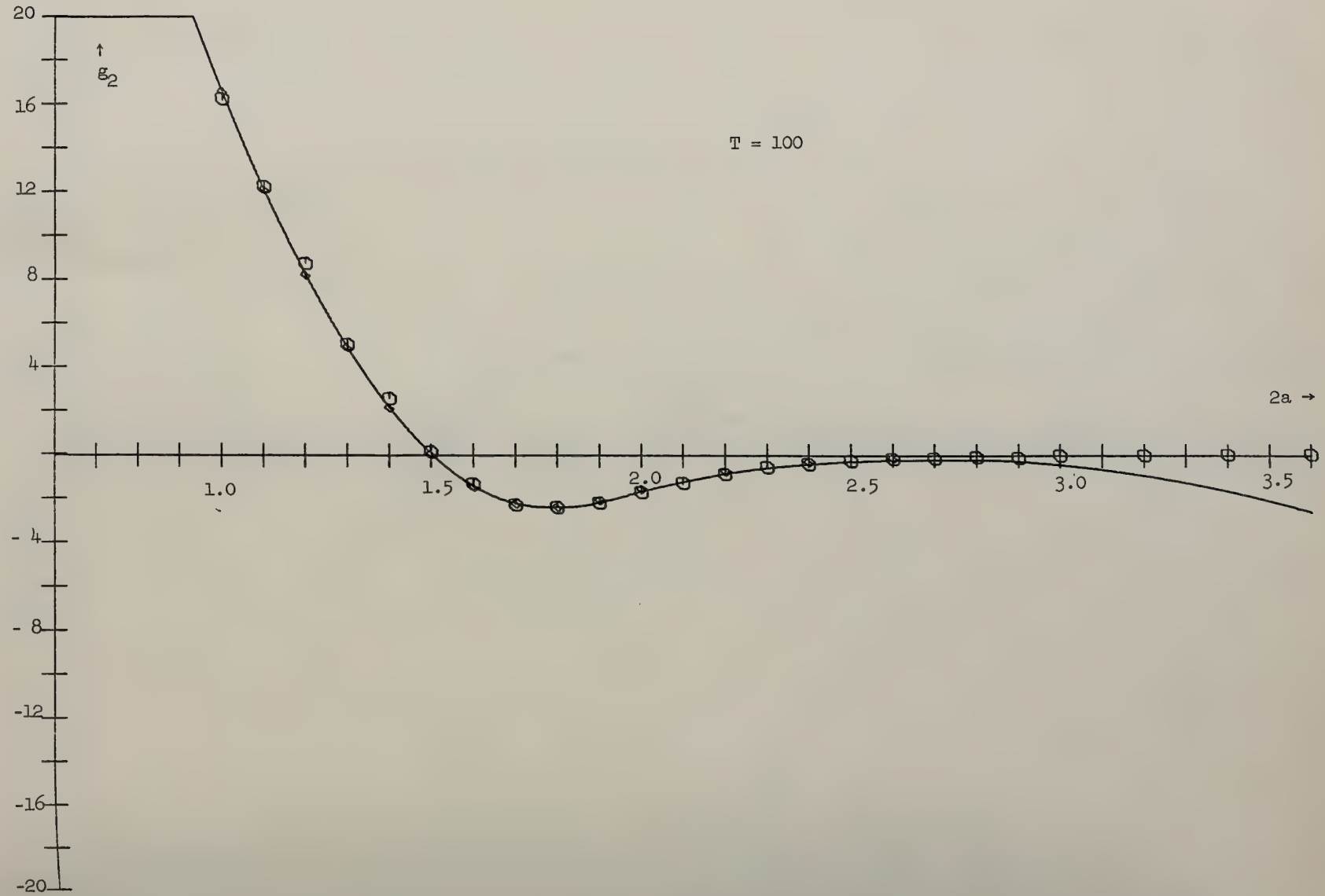

2.0
1.6
1.2
0.8
0.4
-0.4
-0.8
-1.2
-1.6
-2.0
g_2
T = 20
2a →
1.0
1.5
2.0
2.5
3.0
3.5

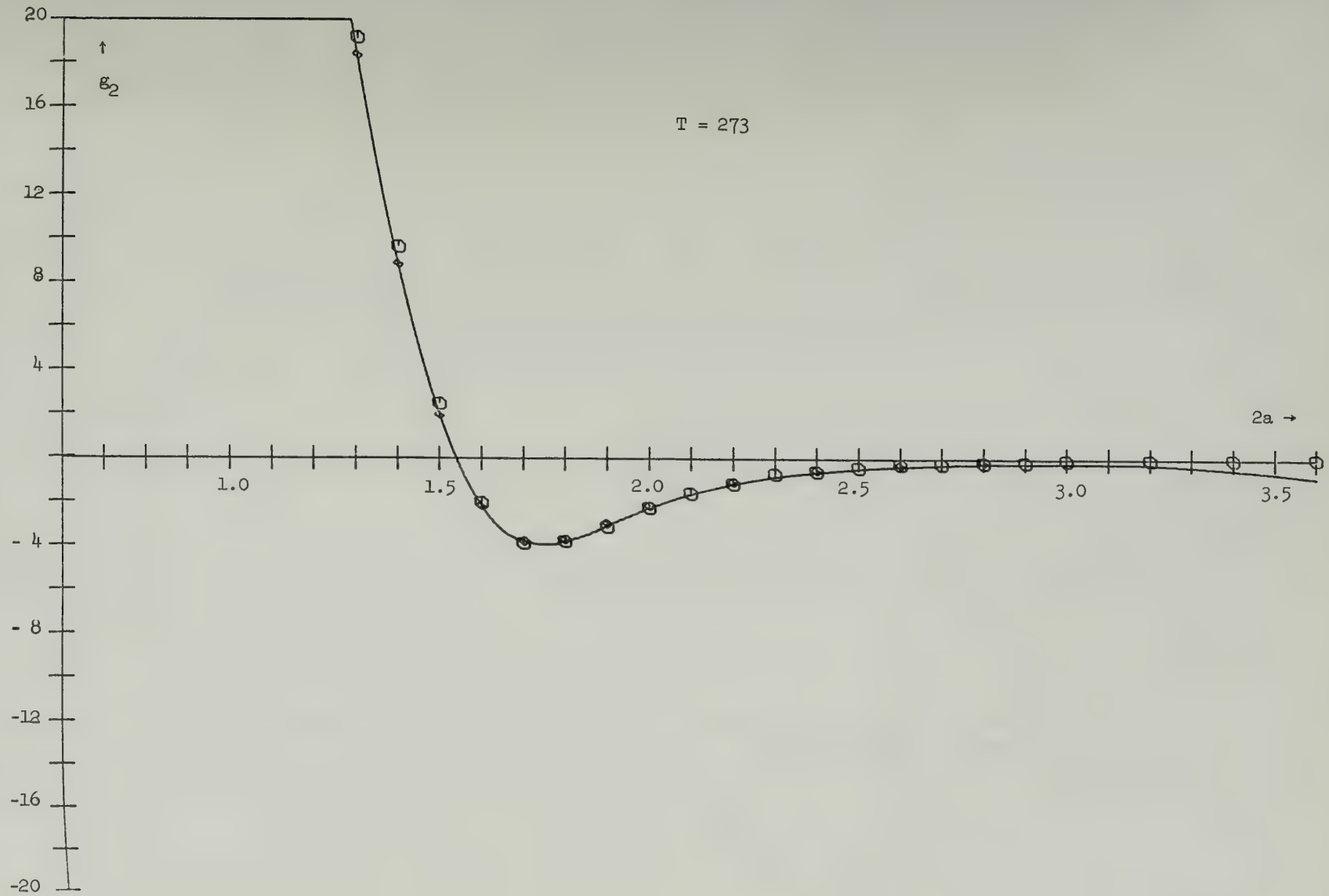

4.0
3.2
2.4
1.6
0.8
-0.8
-1.6
-2.4
-3.2
-4.0
g_2
T = 30
2a →
1.0
1.5
2.0
2.5
3.0
3.5

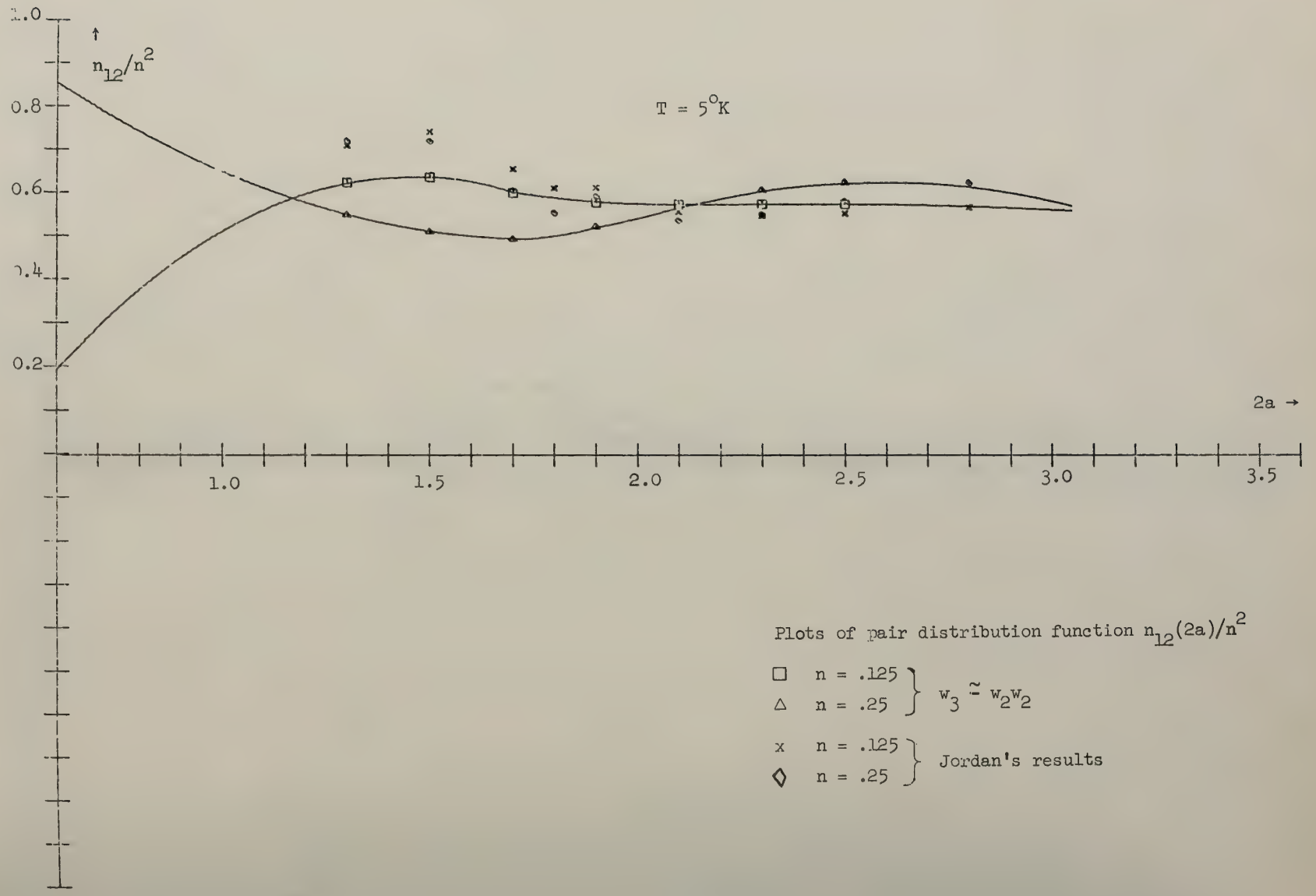

5.0
4.0
3.0
2.0
1.0
-1.0
-2.0
-3.0
-4.0
-5.0
↑
g_2
T = 40
2a →
1.0
1.5
2.0
2.5
3.0
3.5


5.0
4.0
3.0
2.0
1.0
-1.0
-2.0
-3.0
-4.0
-5.0
g_2
T = 50
2a →
1.0
1.5
2.0
2.5
3.0
3.5


10.
8.
6.
4.
2.
- 2.
- 4.
- 6.
- 8.
-10.
g_2
T = 75
2a →
1.0
1.5
2.0
2.5
3.0
3.5


20
16
12
8
4
- 4
- 8
-12
-16
-20
g_2
T = 100
2a →
1.0
1.5
2.0
2.5
3.0
3.5

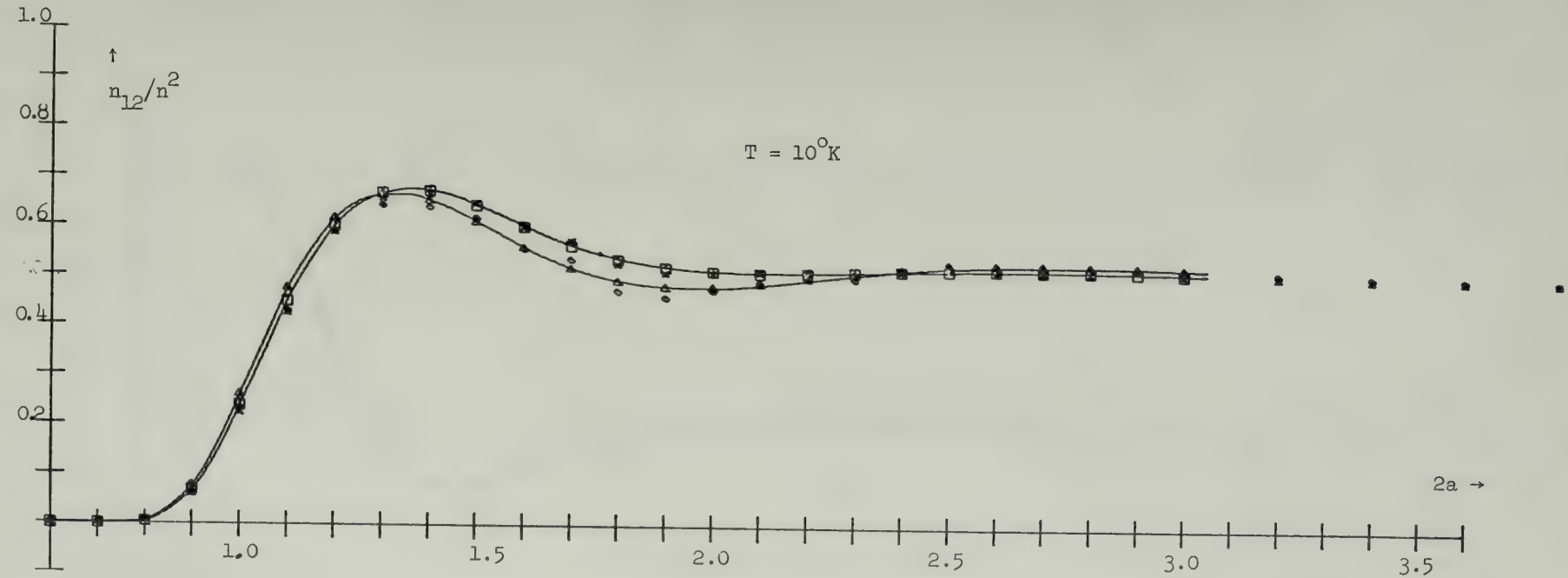

20
16
12
8
4
- 4
- 8
-12
-16
-20
↑
g_2
T = 273
2a →
1.0
1.5
2.0
2.5
3.0
3.5



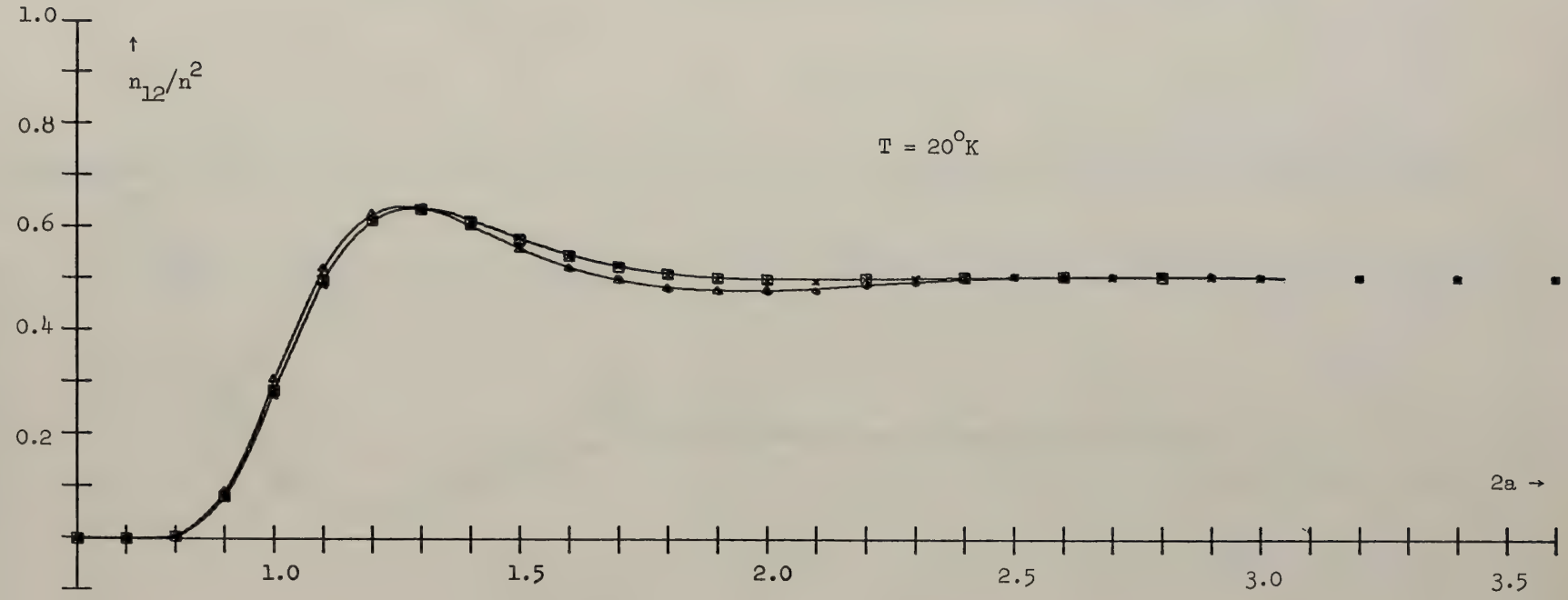
Plots of pair distribution function $n_{12}(2a)/n^2$

□ n = .125
△ n = .25
} $w_3 \simeq w_2 w_2$

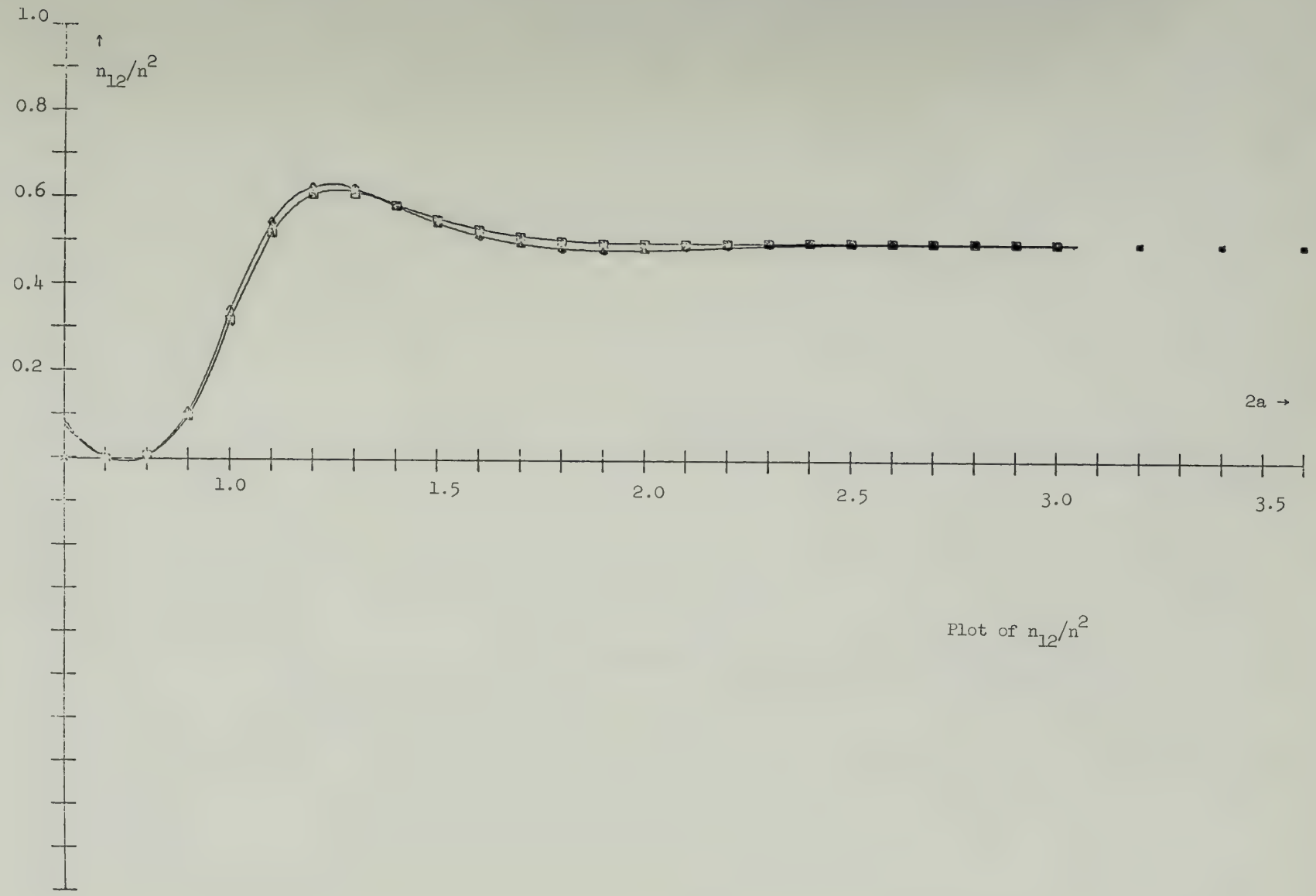
x n = .125
◇ n = .25
} Jordan's results



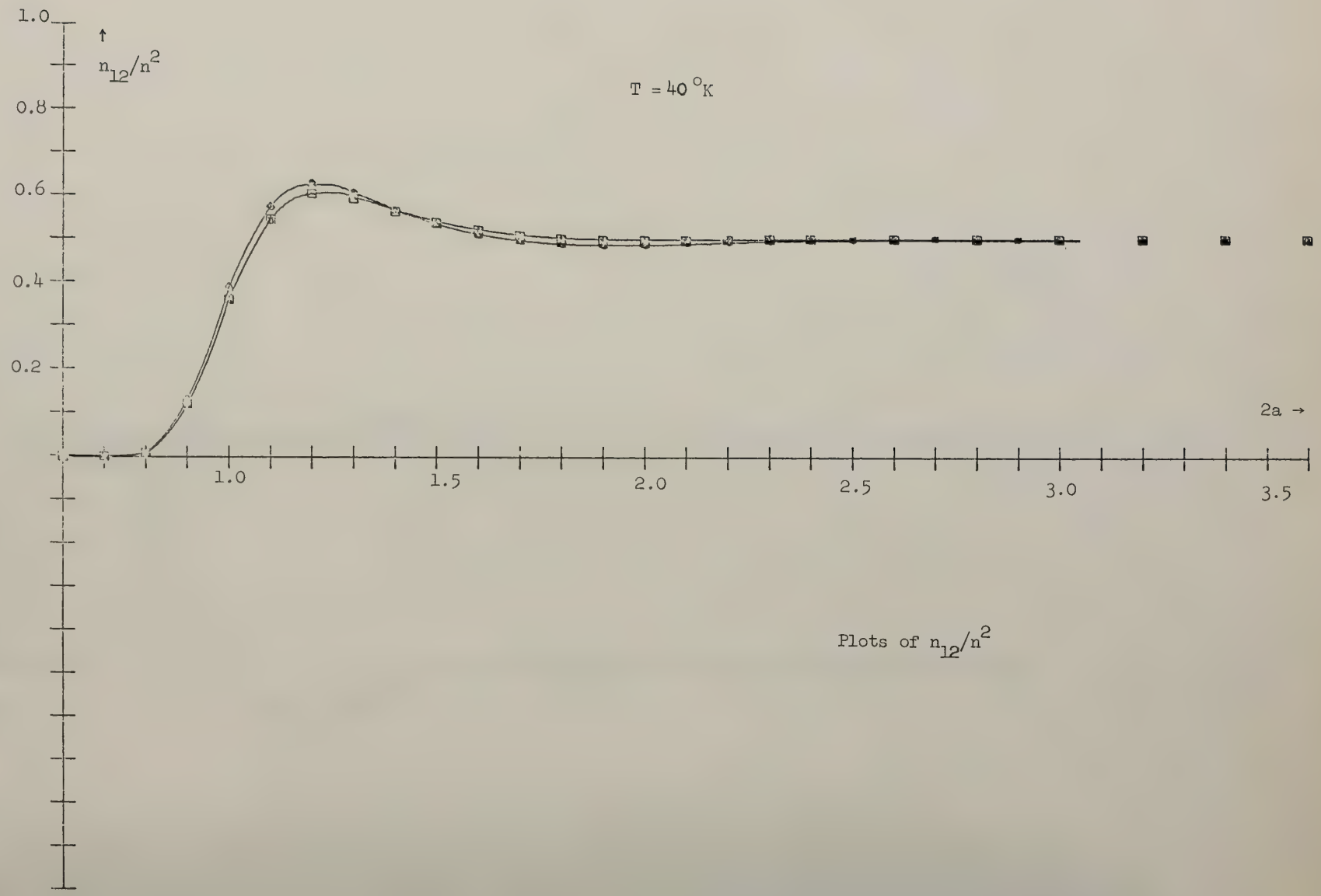
Plots of n_{12}/n^2



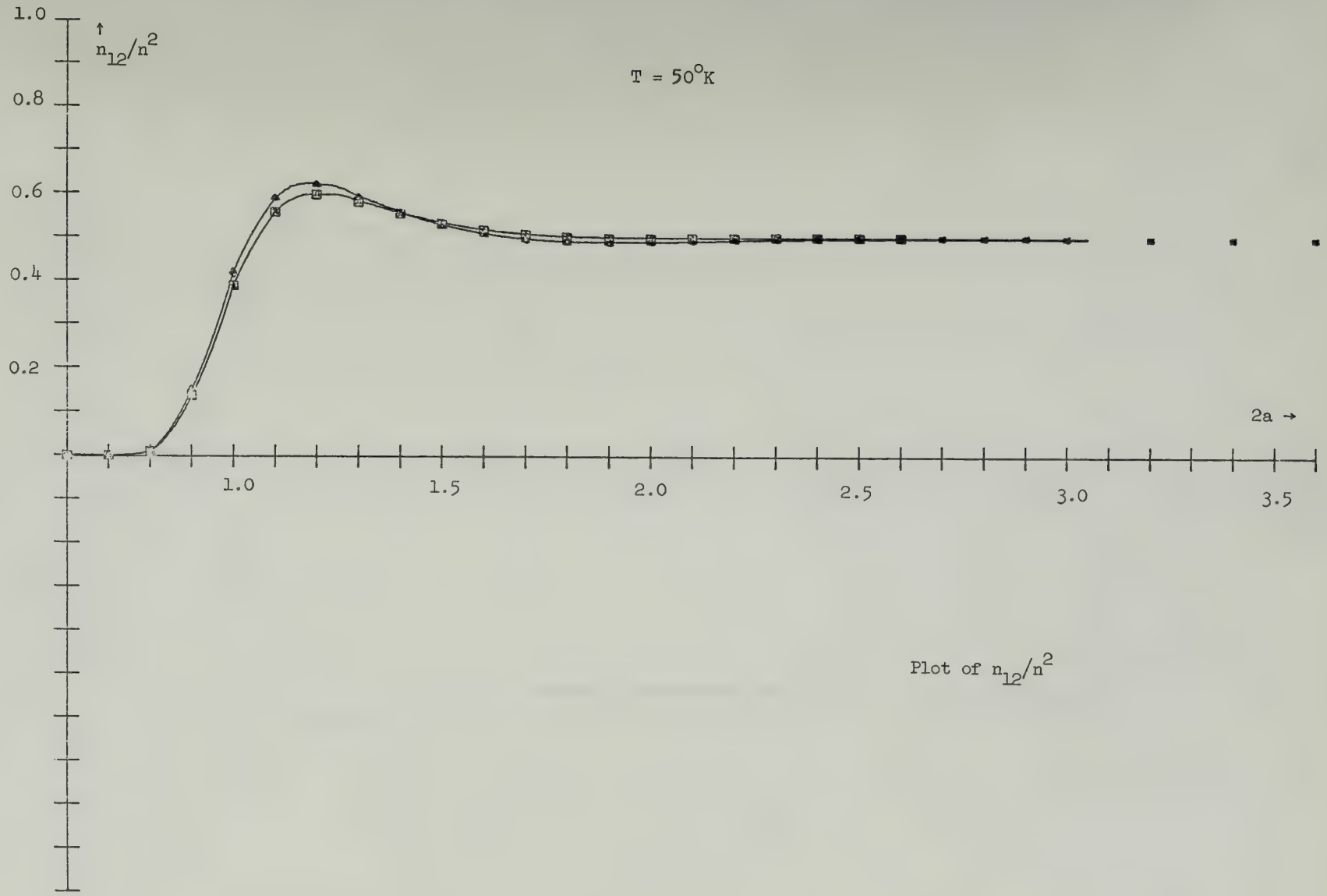
Plots of n_{12}/n^2



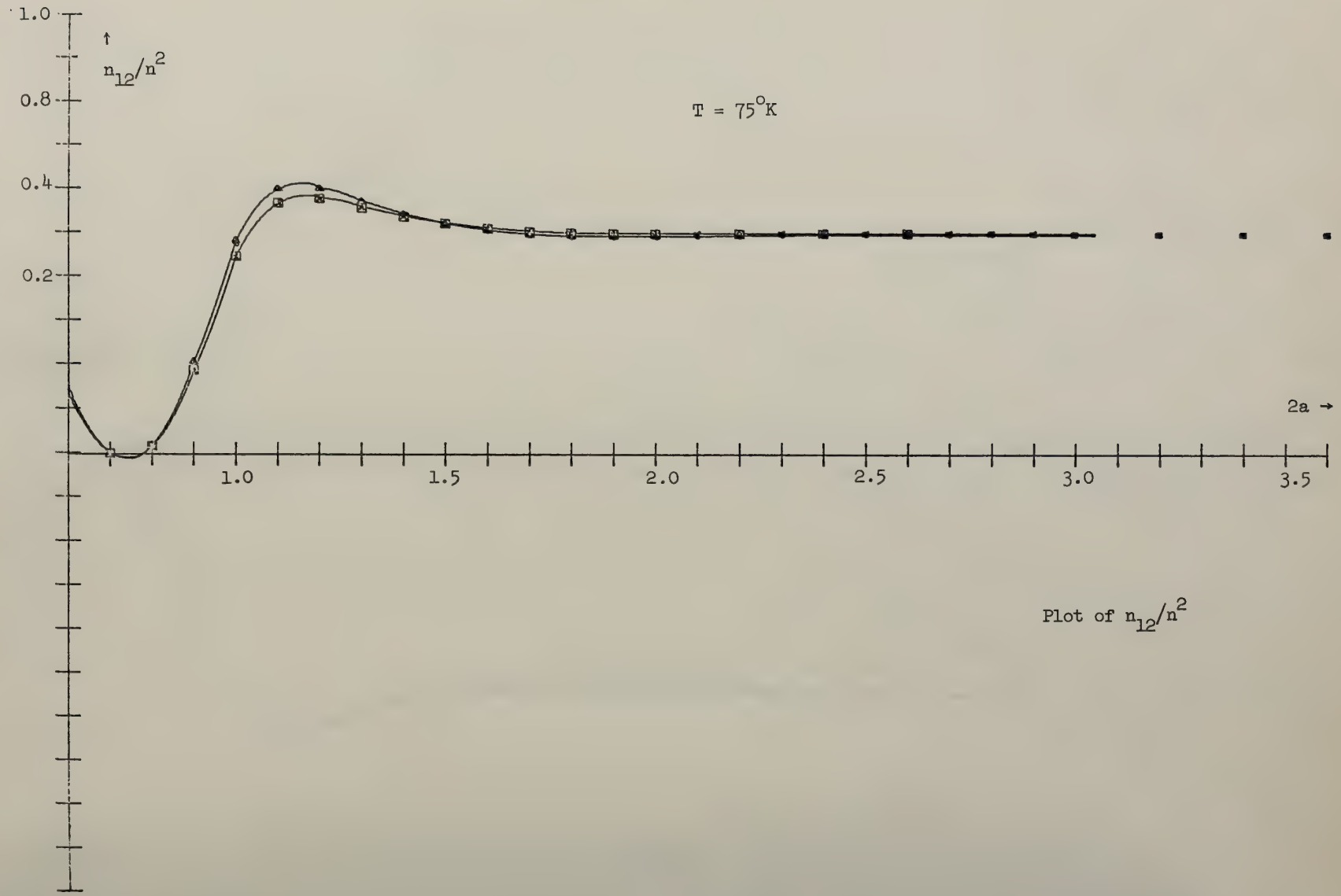
Plot of n_{12}/n^2



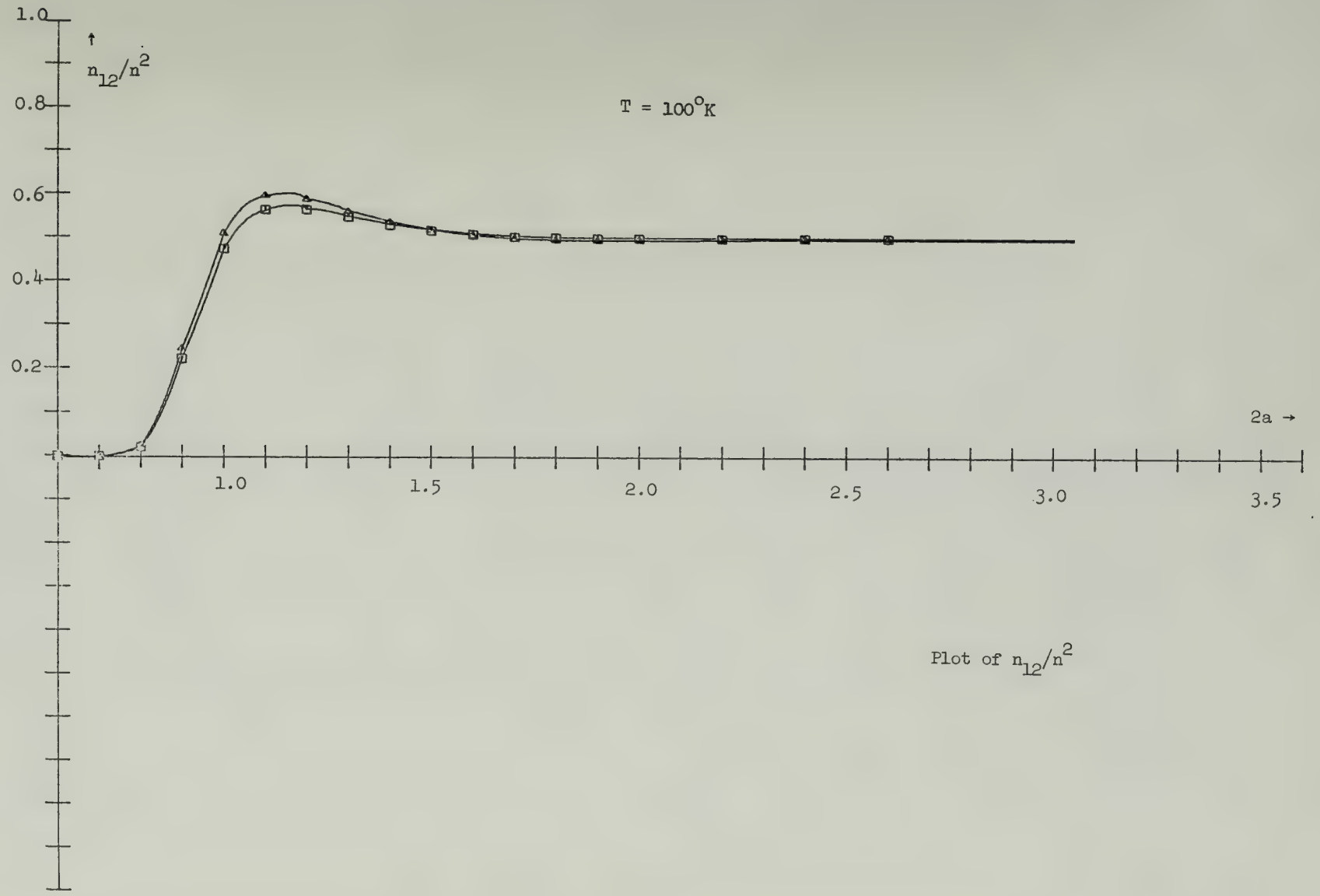
Plots of n_{12}/n^2



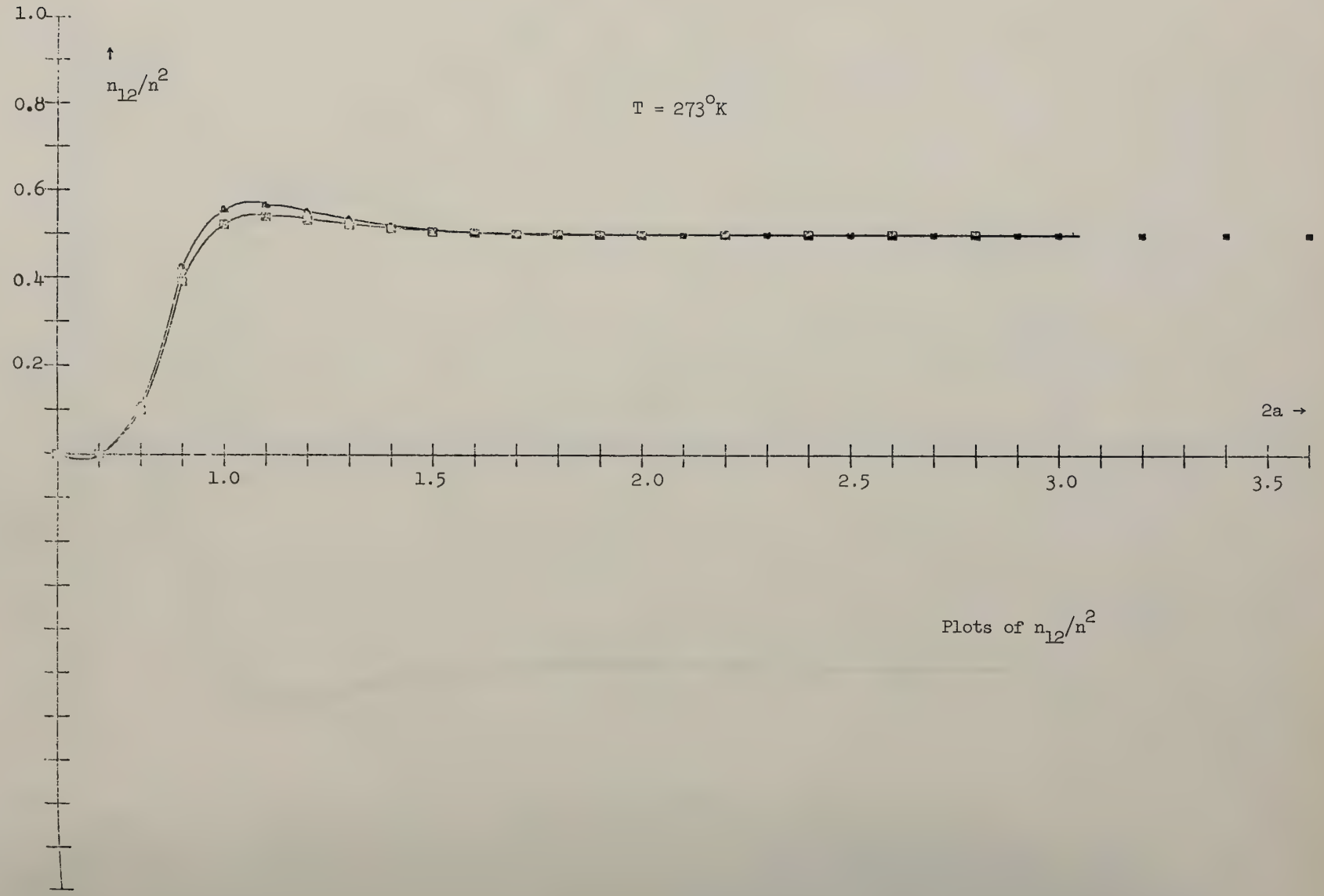
Plot of n_{12}/n^2



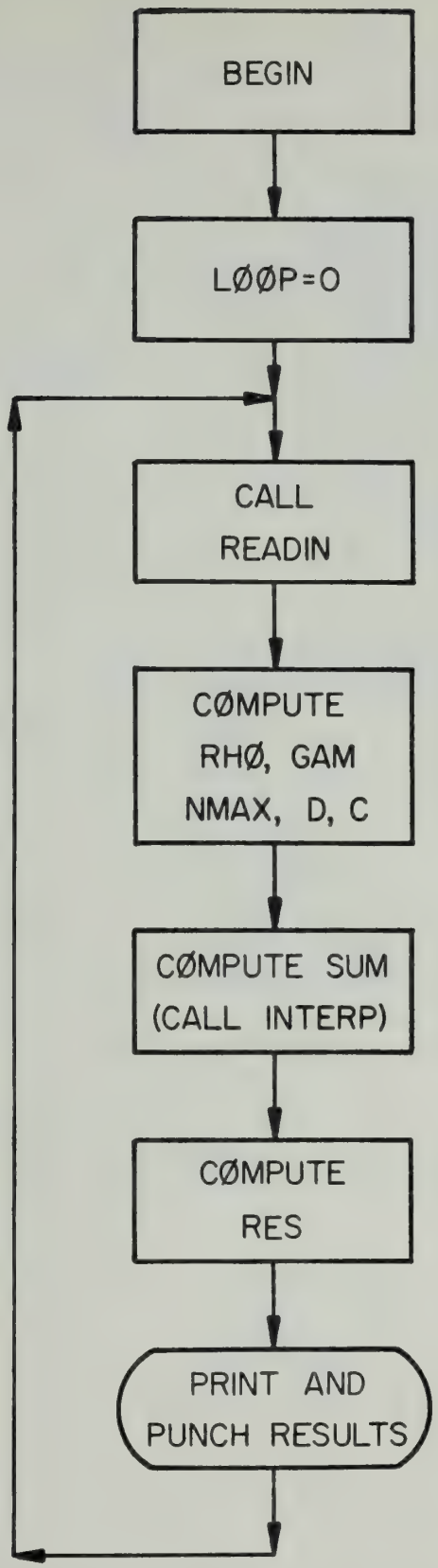
Plot of n_{12}/n^2



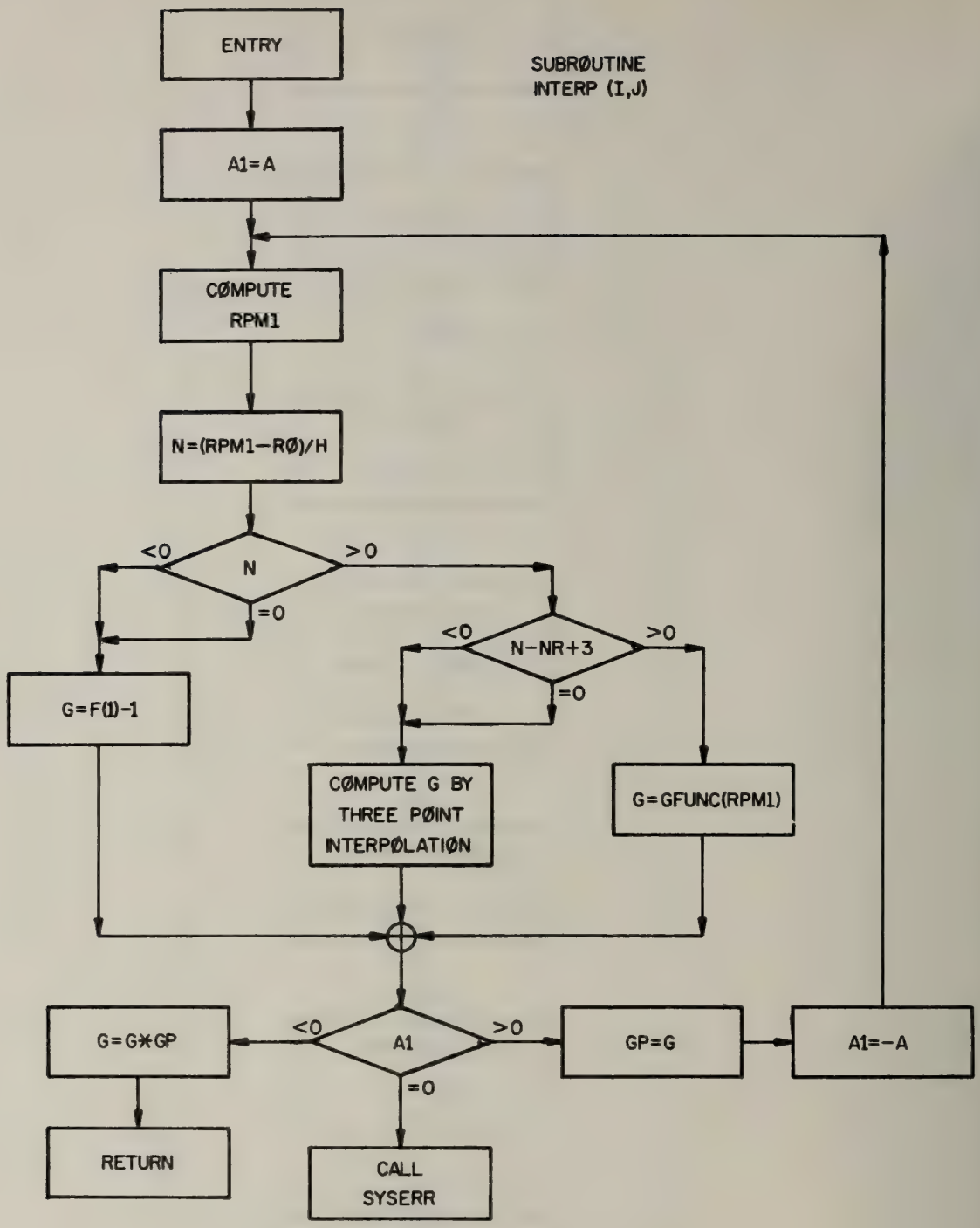
Plot of n_{12}/n^2

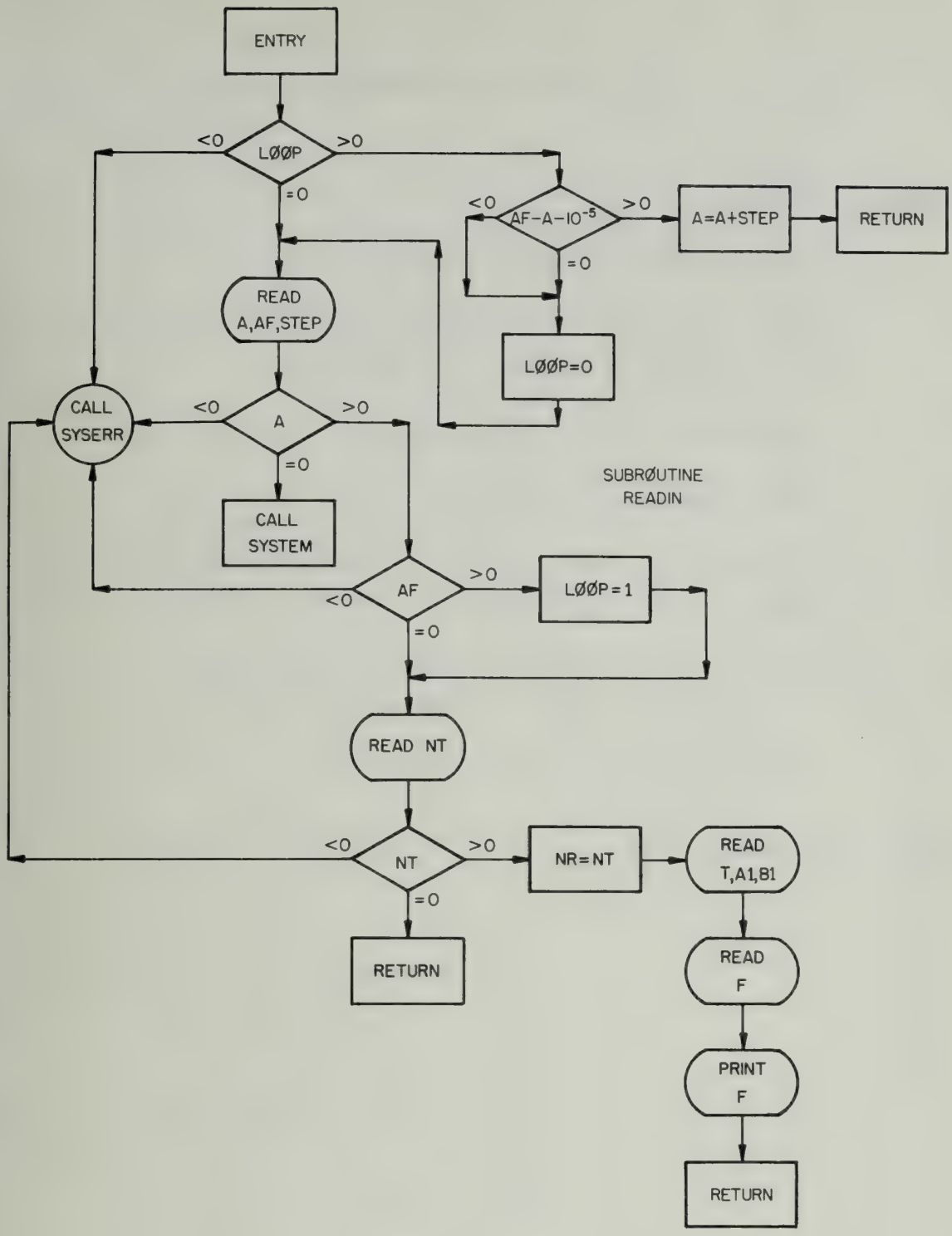


Plots of n_{12}/n^2



BLØCK DIAGRAM ØF MAIN PRØGRAM


ENTRY
SUBRØUTINE
INTERP (I,J)
A1=A
CØMPUTE
RPM1
N=(RPM1−RØ)/H
<0
N
>0
=0
<0
N−NR+3
>0
=0
G=F(1)-1
CØMPUTE G BY
THREE PØINT
INTERPØLATIØN
G=GFUNC(RPM1)
G=G*GP
<0
A1
>0
GP=G
A1=−A
=0
RETURN
CALL
SYSERR


ENTRY
LØØP
<0
>0
=0
AF-A-10-5
<0
>0
=0
A=A+STEP
RETURN
READ
A,AF,STEP
LØØP=0
CALL
SYSERR
A
<0
>0
=0
CALL
SYSTEM
SUBRØUTINE
READIN
AF
<0
>0
=0
LØØP=1
READ NT
NT
<0
>0
=0
NR=NT
READ
T,A1,B1
READ
F
PRINT
F
RETURN
RETURN

Glossary of Symbols Used in the Program Flow Charts

SUBRØUTINE READIN

A	Distance between particles 1 and 2 in units of σ.
A1	First value of R, corresponding to F(1) in the program. (R is argument of $W_2(R)$ in this report)
B1	Second value of R, corresponding to F(2).
AF	Final value of A.
LØØP	Has value 0 if new set of data (temperature, W_2 function, A). LØØP has value 1 if only A is to be changed.
F	Array of the tabulated values of the Slater sum. F corresponds to $W_2(R)$ in the report.
NR	Number of entries in the array F.
STEP	Increment of A.

SUBRØUTINE INTERP(I,J)

A — Half-distance between particles 1 and 2 in units of $\sqrt{2}\,\kappa$. A here corresponds to a in the report.

A1 — Has value $\pm$ A.

G — Value of $W_2(R_{ij}^{+})$ computed by subroutine.

Gp — Corresponds to $W_2(R_{ij}^{+})$ in report.

H — Spacing of the R's corresponding to array F (see SUBRØUTINE READIN) in units of $\sqrt{2}\,\kappa$.

RO — Initial value of R.

RPM1 — Corresponds to $R_{ij}^{\pm}$ in report.

MAIN PRØGRAM

LØØP — Same as in READIN.

C — Corresponds to c in report.

D — Corresponds to d in report.

GAM — Corresponds to γ in the report.

RHØ — Corresponds to ρ in the report.

RES — Corresponds to Res in the report in units of λ^3.

```
C     PRØGRAM FØR CALCULATING THE INTEGRAL ØF (W(1,3)-1)(W(2,3)-1)
C
C     THE INTEGRAL IS IN UNITS ØF LAMBDA CUBED.
C     THE ØRDER ØF THE CARDS ARE AS FØLLØWS.
C     CARD 1.  DISTANCE (IN SIGMA) BETWEEN ATØMS (A)
C              (INITIAL VALUE, FINAL VALUE, STEP)    (3E20.0)
C     CARD 2.  TØTAL NUMBER ØF INPUT VALUES ØF FUNCTIØN
C              W2 FØR PARTICULAR TEMPERATURE.        (I80)
C     CARD 3.  TEMPERATURE (T) AND THE FIRST TWØ VALUES
C              ØF R FØR THE TABULATED FUNCTION W2    (F10.0,2E14.8)
C               (R IS IN UNITS ØF SQRT(2)*LAMBDA-BAR)
C     CARDS 4 TØ - .  VALUES ØF THE FUNCTIØN W2      (5E14.8)
C
C     THE NEXT CARD IS A BLANK IF THE PRØGRAM IS TØ BE TERMINATED.
C     HØWEVER, IF CALCULATIØNS FØR ØTHER PARAMETER VALUES ARE
C     DESIRED, THE CARDS MAY BE ADDED USING THE ABØVE PRØCEDURE.
C     THE VERY LAST CARD ØF THE DATA DECK SHØULD BE BLANK.
C
C     IF ØNLY A IS TØ BE CHANGED, ADD ØNLY THE CARD SPECIFYING A
C     FØLLØWED BY A BLANK FØLLØWED BY THE NEXT VALUE ØF A FØLLØWED
C     BY A BLANK ETC.  THE PRØGRAM IS TERMINATED WHEN A=0.
C
      FUNCTIØN GFUNC(X)
      DIMENSIØN F(200)
      CØMMØN RO,H,D,NR,A,RHØ,GAM,T,F,G
      R2=1./RHØ**2
      X2=(RHØ/X)**2
      X6=X2**3
      GFUNC=EXP(GAM*X6*(1.+R2*X2*(2.5+X2*(7.*R2-X2*(1./R2-X2*(1.5*GAM-11
      1.))))))
      RETURN
      END
```

```
      SUBRØUTINE READIN
      DIMENSIØN F(200)
      CØMMØN RO,H,D,NR,A,RHØ,GAM,T,F,G,C,LØØP
      IF (LØØP) 11,14,35
14    READ 1,A,AF,STEP
1     FØRMAT (3E20.0)
      IF (A) 11,2,33
2     CALL SYSTEM
33    IF (AF) 11,3,34
34    LØØP = 1
      GØ TØ 3
35    IF (AF-A-1.E-5) 36,36,37
36    LØØP = 0
      GØ TØ 14
37    A = A+STEP
      RETURN
3     READ 10,NT
10    FØRMAT (I80)
      IF (NT) 11,12,13
11    CALL SYSERR
12    RETURN
13    NR = NT
      READ 20,T,A1,B1
20    FØRMAT (F10.0,2E14.8)
      RO = A1
      H = B1-A1
      READ 30, (F(I), I = 1,NR)
30    FØRMAT (5E14.8)
      PRINT 40,T,NR,H,RO
40    FØRMAT (23H1 INPUT DATA FUNCTIØN W2/14H TEMPERATURE = F4.0,14H DEGREE
     1S KELVIN/19H NUMBER ØF PØINTS = I3/10H SPACING = E14.8,16H INITIAL P
     20 INT = E14.8)
      NR4 = NR/4
      DO 4 I = 1,NR4
      J1 = NR4+I
      J2 = NR4+J1
      J3 = NR4+J2
      PRINT 50,I,F(I),J1,F(J1),J2,F(J2),J3,F(J3)
50    FØRMAT (4H W2(I3,3H) = E14.8,6H  W2(I3,3H) = E14.8,6H  W2(I3,3H) =
     1E14.8,6H  W2(I3,3H) = E14.8)
4     CØNTINUE
      NR44 = 4*NR4
      M = NR-NR44
      I1 = NR44 + 1
      I2 = I1+1
      I3 = I2+1
      IF (M) 11,46,47
46    RETURN
47    IF (M-2) 5,6,7
5     PRINT 60,I1,F(I1)
      RETURN
6     PRINT 60,I1,F(I1),I2,F(I2)
      RETURN
7     PRINT 60,I1,F(I1),I2,F(I2),I3,F(I3)
      RETURN
60    FØRMAT (82H  W2(I3,3H) = E14.8)
      END
```

```
      SUBRØUTINE INTERP(I,J)
      DIMENSIØN F(200)
      CØMMØN RO,H,D,NR,A,RHO,GAM,T,F,G,C,LØØP
      RPM (AI,AJ,A)=SQRT(((AI-.5)*D+A)**2+(AJ-.5)*C)
      AI = I
      AJ = J
      A1 = A
10    RPM1 = RPM(AI,AJ,A1)
      N = (RPM1-RO)/H
      AN = N
      NA = N+1
      IF (N) 70,70,11
11    IF (N-NR+3) 12,12,80
12    RA = AN*H+RO
      IF (RPM1-RA) 20,40,40
20    RB = RA
      RA = RA-H
      NB = NA
      NA = NA-1
      GØ TØ 50
40    RB = RA+H
      NB = NA+1
50    NC = NB+1
      RC = RB+H
      R1A = RPM1-RA
      R1B = RPM1-RB
      R1C = RPM1-RC
      G = (R1B*R1C*F(NA)/2.-R1A*R1C*F(NB)+R1A*R1B*F(NC)/2.)/H**2-1.
52    IF(A1) 60,90,51
51    GP = G
      A1 = -A
      GØ TØ 10
90    CALL SYSERR
60    G = G*GP
      RETURN
70    G = F(1)-1.
      GØ TØ 52
80    G = GFUNC(RPM1)-1.
      GØ TØ 52
      END
```

```
      DIMENSIØN F(200)
      CØMMØN RO,H,D,NR,A,RHO,GAM,T,F,G,C,LØØP
      LØØP = 0
      PI4 = 2./SQRT (3.1415926536)
1     CALL READIN
      D = H
      RHØ = .256*SQRT (3.34504*1.38054*T)/1.05443
      GAM = 56.16/(1.38054*T)
      RHØ1 = 2.2*RHO
      IF (RHO1-16.0) 10,10,20
10    NMAX = 16./D
      GØ TØ 30
20    NMAX = RHO1/D
30    ANM = NMAX
      PRINT 2,NMAX
2     FØRMAT (//7HONMAX = 17)
      PRINT 13,D
13    FØRMAT (4H D = E14.8)
      C = NMAX*D**2
      D3 = C*D
      AT = A
      A = A*RHØ/2.
      S = 0.
      DO 40 I=1,NMAX
      DO 40 J=1,NMAX
      CALL INTERP (I,J)
40    S = S+G*D3
      S = S*PI4
      RZ9 = (RHØ/(ANM*D-A))**9
      RR9 = (RHØ/ANM/D)**9
      RES = PI4*(GAM*RHØ)**2*(RZ9/45.+.0858*RR9+.145*RR9*A/ANM/D)*RHØ
      A = AT
      Q = (RES/S)*100.
      PRINT 50,T,A,S,RES,Q
50    FØRMAT (//14H TEMPERATURE = F4.0/25H DISTANCE BETWEEN ATØMS = 1PE15
     1.8//11H INTEGRAL = 1PE15.8/18H RESIDUE LESS THAN 1PE15.8/16H PERCENT
     2 ERRØR = 1PEC10.3)
      ID = 21
      PUNCH 3,ID,T,A,S
3     FØRMAT (I10,3E14.8)
      GØ TØ 1
      END
```

7. SWITCHING THEORY AND LOGICAL DESIGN

Logical design of an optimum network under fan-ins and fan-outs requirements has been an unsolved problem of switching theory. In 1965, S. Muroga proposesd a new procedure using integer linear programming which is based upon threshold logic. Usefulness of the procedure depends entirely upon the computational efficiency of algorithms of integer linear programming.

C. Baugh, T. Ibaraki and S. Muroga employed Gomory's all integer-integer algorithm. After spending considerable time with ILLIAC II they discovered that Gomory's all integer-integer algorithm is not sufficiently efficient. A program for three NOR gates realization took a few minutes, regardless of whether a given function is realizable with three gates or not.

Programs for four or more gate realizations needed the use of a magnetic drum. Even four gate realization took considerable time. However, it was amazingly fast for the size of a matrix of about 90 variables and about 140 inequalities. Probably this was the largest matrix on which Gomory's all integer-integer algorithm has been used successfully. In these programs a few techniques to reduce computation time were incorporated, such as changing the order of inequalities and adding constraints based upon the circuit configuration. The techniques were very effective. When the inequalities for the last NOR gates are placed at the top of the entire set of inequalities, reduction of the computation time was the greatest. The additional constraints based on the circuit configuration greatly reduced symmetrical combinations of binary variables.

F. Chen programmed the logical design of an optimum circuit with threshold gates whose weights are 1, -1 or 0. He employed Gomory's all integer-integer algorithm on the IBM 7094. He also developed a packing technique for storing the sparce coefficient matrix. The computational efficiency was very discouraging. Even two gate realization was difficult.

The conclusion about the computational efficiency of Gomory's all integer-integer algorithm is as follows. It is very poor for our logical design problem, even though it is amazingly good for the size of the matrix. We decided to try other algorithms.

T. Slivinski wrote a very interesting Ph.D thesis. He obtained many results, extending basic results of threshold logic to the case of pseudo threshold functions. A necessary and sufficient condition for a function to be a threshold function was stated in a very simple way. Circuit synthesis of a pseudo-threshold function was also studied. This thesis is available as departmental report number 228.

T. Ibaraki and S. Muroga pursued two unrelated theoretical problems, an adaptive network and a logical design of an optimum network using only a given set of building blocks. The first problem was formulated with integer linear program and the resulting adaptive network has always the best reliability of the operation. The second problem was also formulated with integer linear programming, representing building blocks with a set of inequalities. They are preparing reports about these two problems.

S. Muroga

8. ILLIAC II SERVICE, USE, AND PROGRAM DEVELOPMENT

(This work is supported in part by Contract No. AT(11-1)-1469 of the Atomic Energy Commission and in part by the University of Illinois.)

8.1 ILLIAC II Program Development

(See Section 3.)

8.2 Library Programming

8.2.1 ILLIAC II Library Development

During this period the following subroutines were added to the library:

E2-U0I-ORT1-111-FR

IDENTIFICATION--A FORTRAN subroutine to solve Linear Equations and Least Squares Problems by Elimination with Weighted Row Combinations.

PURPOSE--The several entry points to this subroutine and their purposes follow.

ORT1: Given a real NxM matrix A with rank M and B a real NxK matrix, subroutine ORT1 computes a real NxK matrix X such that

$$||B_I - AX_I|| = \min.$$

where ||----|| indicates the Euclidean norm, B_I and X_I are the Ith column vector of B and X respectively.

ORT2: Given a real NxM matrix A with rank M and b a n-dimensional vector, subroutine ORT2 computes a n-dimensional vector X such that

$$||b-Ax|| = \min.$$

ORT3: Given a real NxM matrix A with rank N, subroutine ORT3 computes a matrix V which is the inverse of the matrix A.

ORT4: It is the same as ORT3 but the output matrix V is stored in the input matrix A.

E2-UOI-LEAST-112-FR

IDENTIFICATION--Linear least squares solutions by Householder Transformation for FORTRAN.

PURPOSE--Given a real MxN matrix A with rank N and B a real MxP matrix, this program computes a real NxP matrix X such that

$$||B_I - AX_I|| = \min.$$

where ||---|| indicates the Euclidean norm, B_I and X_I are the Ith column vectors of B and X respectively.

If M=N, this program computes a real NxP matrix X such that

$$B-AX = 0 \quad .$$

During this period a number of ILLIAC II library subroutines were converted for use on the IBM 360, model 50 and were checked at the IBM Data Center in Chicago. The following routines have been checked and found to work. Because of the circumstances, the testing of these routines has not been as thorough as desired and further checks will be made after the arrival of our own 360.

E2-UOI-WLSQ-48-FR

IDENTIFICATION--A complete FORTRAN program for weighted lease squares polynomial approximation.

PURPOSE--To compute the weighted least squares polynomial approximation for a function y(x), whose values are known only at a set of n points $x_1, x_2, \ldots, x_n$; the corresponding values are $y_1, y_2, \ldots, y_n$, respectively. The weights, representing the relative accuracy of the values y_i, are $w_1, w_2, \ldots, w_n$. The weighted least squares polynomial

approximation of degree q is represented by

$$f_q(x) = \sum_{j=0}^{q} a_j x^j \quad .$$

D1-UOI-GQU3-72-FR

IDENTIFICATION--Legendre-Gauss Quadrature for FORTRAN.

PURPOSE--This is a FORTRAN subroutine to evaluate the integral:

$$\int_a^b f(x)\, dx \quad .$$

D1-UOI-GQU4-73-FR

IDENTIFICATION--Hermite-Gauss Quadrature for FORTRAN.

PURPOSE--This is a FORTRAN subroutine to evaluate the integral

$$\int_{-\infty}^{+\infty} e^{-x^2} f(x)\, dx \quad .$$

D1-UOI-GQU5-74-FR

IDENTIFICATION--Laguerre-Gauss Quadrature for FORTRAN.

PURPOSE--This is a FORTRAN subroutine to evaluate the integral

$$\int_0^{+\infty} e^{-x} f(x)\, dx \quad .$$

D1-UOI-GQU6-75-FR

IDENTIFICATION--Two-Dimensional Quadrature for FORTRAN.

PURPOSE--This is a FORTRAN subroutine to evaluate the integral:

$$\int_D \int f(x,y)\, dx\, dy \quad .$$

D1-UOI-GQU8-76-FR

IDENTIFICATION--Gauss-Jacobi Quadrature for FORTRAN.

PURPOSE--This is a FORTRAN subroutine to evaluate the integral:

$$\int_{-1}^{1} (1+x)^{\beta} f(x)dx \quad ; \quad \beta = 1, 2, 3, 4 \quad .$$

D1-UOI-GQU7-77-FR

IDENTIFICATION--Gauss-Jacobi Quadrature for FORTRAN.

PURPOSE--This is a FORTRAN subroutine to evaluate the integral:

$$\int_{-1}^{1} (1-x^2)^{\alpha} f(x)\, dx \quad ; \quad \alpha = -\frac{1}{2}, \frac{1}{2}, 1, \frac{3}{2} \quad .$$

D1-UOI-GQU9-78-FR

IDENTIFICATION--Gaussian Quadrature for FORTRAN.

PURPOSE--This is a FORTRAN subroutine to evaluate the integral:

$$\int_{-1}^{1} |x|^{\alpha} f(x)\, dx \quad ; \quad \alpha = 1, 2, 3, 4 \quad .$$

D1-U0I-GQU10-79-FR

IDENTIFICATION--Gaussian Quadrature for FORTRAN.

PURPOSE--This is a FORTRAN subroutine to evaluate the integral:

$$\int_0^1 \ell n \left(\frac{1}{x}\right) f(x)\, dx \quad .$$

D1-U0I-GQU11-80-FR

IDENTIFICATION--Gaussian Quadrature for FORTRAN.

PURPOSE--This is a FORTRAN subroutine to evaluate the integral:

$$\int_{-\infty}^{\infty} |x|^{\alpha} e^{-x^2} f(x)\, dx \quad ; \quad \alpha = 1, 2, 3 \quad .$$

D1-U0I-GQU12-81-FR

IDENTIFICATION--Gaussian Quadrature for FORTRAN.

PURPOSE--This is a FORTRAN subroutine to evaluate the integral:

$$\int_{-\infty}^{\infty} |x|^{\alpha} e^{-|x|} f(x)\, dx \quad ; \quad \alpha = 1, 2, 3 \quad .$$

F2-U0I-HOUSE-97-FR

IDENTIFICATION--Householder's method for symmetric matrices, a FORTRAN subroutine.

PURPOSE--Reduces a symmetric matrix to tridiagonal form.

F2-U0I-CEST1-100-FR

IDENTIFICATION--CEST1 for FORTRAN.

PURPOSE--CEST1 finds the eigenvalues of a symmetric, tridiagonal matrix by the method of bisection.

F2-U0I-LRCH-104-FR

IDENTIFICATION--A FORTRAN subroutine for eigenvalue calculation.

PURPOSE--Calculates the eigenvalues of a symmetric positive definite matrix by the LR transformation method.

L. D. Fosdick, Project Director
R. Bow
S. Chase
R. Fleck
T. Kuckertz
B. Richardson
N. Smith

8.3 The CalComp Plotter

The total number of hours the plotter ran for this period are as follows:

April	345 hours
May	301 hours
June	394 hours

Well over 1000 jobs a month from the 7094 alone, run on the CalComp plotter. Both April and June exceeded, by over 30 hours, the 2 shift - 5 day operation. Most generally there is a back log of 2 to 3 days. Some time a back log of 5 days was reached.

The CalComp 780-763 Zipmode system was again at our lab for demonstration during the North American Architects Institute Conference. It again shows the great time difference between it and our present 670-564 System. Some experiments were made to show how much faster it is than our present plotter.

T. E. Kerkering

8.4 Engineering Maintenance Software

1. A Read-A-Round test for the PDP-7 channel was made a part of the cavities tape.
2. An inter-record-gap test for the 729 IBM-ILLIAC II mag. tapes tapes has been written and checked out.
3. The flow gating test was added to the cavities tape.

8.5 Engineering Maintenance

8.5.1 Multiplexer

The 173 Multiplexer that was installed in the PDP-7 has been checked out. A problem still exists with the address bits when running the RAR test.

The Data Interrupt Multiplexer type 173, that had been installed earlier this year in the PDP-7, drawings (D-173-0-2 and D-173-0-3) have been checked against the check print. With a few corrections they will be ready to go to the photo lab for the final drawings.

8.5.2 PDP-7 to 2701 Interface for the 360

The jumpers and card to card wiring has been completed for racks 3H and 3J. The rack has been installed in bay 3 of the PDP-7. The rack to rack wiring has been started but not completed. Three IBM cable connectors have been placed in a rack panel in preparation to wiring. Seven receiver cards and seven transmitter cards were built and checked out.

The rack to rack wiring has been completed in bay 3 of the PDP-7 to 2701 interface for the 360. Wiring to the three I.B.M. cable connectors have been completed.

The indicator panel above bay 3 in the PDP-7 has been drilled and made ready for mounting the indicator boards.

8.5.3 PDP-8 and 338

A wiring list was taken from a new interface drawing to the 630. The rack was then wiring and installed above the PDP-8 processor. Five cables had to be made in order to tie the logic to the necessary destinations. The 630 was also modified such that port "01" (to be eventually wired for port "00") using D.C. loop and half duplex mode became a single port entry for transmitting and receiving.

The old PDP-8 had its modifications (see IOHGM-37) removed and rewired as it originally came in. The old PDP-8 was then checked out, dismantled, crated and prepared for shipment to the Digital Equipment Corporation.

A drawing (D-8P-0-60) has been sent to the drafting room and a check print of the final drawing has been received for the PDP-8 to 630 interface.

The final print for the PDP-8 to 630 interface has been checked out and final prints received for engineering books.

Mr. Gilbert Slaw from Digital Equipment Corporation was called in to repair memory module one during the latter part of May. It was found that the reference supply was not regulating. He also checked on the 338 display 60 cycle jitter. The reason for the jitter has not been determined as of this time.

On June 19, 1967, the Digital Equipment Corporation engineers arrived to install and check out the PDP-8 data multiplexer (DMØ1) and two DEC tape drives TU-55 with control TCØ1.

Some amount of time was spent in looking into integrated circuits. Checkout of the PDP-7 interface wiring to the 360 will be done with a simulator USW6 integrated circuit logic. A preliminary drawing has been made for the simulator which allowed data to be taken to process the order for the IC's.

Additional IC's have been ordered so that sufficient 14-lead dual in-line plastic integrated circuits will be in the laboratory to construct the 2701 simulator in the PDP-7.

H. E. Lopeman and R. L. Miller

The D/A and A/D converter was redesigned and other changes made to allow the required operation. This was checked out.

A. Otis and R. L. Miller

8.5.4 ILLIAC II Engineering Log Summary - April, May, June, 1967

Error Analysis - ILLIAC II	April	May	June	Total
Advanced Control		1		1
Core 0	4	1	1	6
Core 1	2	2	0	4
Flow Gating			1	1
Power Supplies	1	3	2	6
SPU Channel		1		1
Tape Units	5	3	4	13
Air Conditioning	1	2		3
Paper Tape Reader Punch	1	1		2
1401	1		1	2
1402	1	1		2
	16	15	10	41

8.5.5 Scheduled Diagnostic Engineering

1. D.C. marginals on the C.P.U. were run once a week during the months of April, May, and June.
2. Module "a" of core "0" is a useable spare after some time of trouble.
3. The 2N1072's in the X-Y drivers of core "1" were checked for BV_{bc0} = 75 V @ 1 ma.
4. The inter-record-gap test was used on all tapes. All tape drives are being adjusted to run this test properly.

8.5.6 Log Summaries

8.5.6.1 ILLIAC II Use

8.5.6.1.1 Summary of Use

April, 1967

Scheduled Engineering	59:50
Unscheduled Engineering	3:36
Engineering Development	9:42
Time-Sharing Development and Operation	194:15
Power Off	400:00
Miscellaneous (operating, tape rewind, tape skipping, tape mounting, rerun of failures, starts of time-sharing)	23:33

Total Use

Training and Education		5:32	
System Development		10:01	
Customer Use			
In Systems	13:17		
Short Shots	:14		
Customer Use		13:01	
		Total Use	29:04
		Total Time	720:00

May, 1967

Scheduled Engineering			65:00
Unscheduled Engineering			15:28
Engineering Development			28:12
Time-Sharing Development and Operation			124:55
Power Off			392:00
Miscellaneous (operating, tape rewind, tape skipping tape mounting, rerun of failures, starts of time-sharing)			45:57
Total Use			
Training and Education		7:51	
System Development		11:36	
Customer Use			
In Systems	52:54		
Short Shots	:07		
Customer Use		53:01	
		Total Use	72:28
		Total Time	744:00

June, 1967

Scheduled Engineering	67:00
Unscheduled Engineering	39:50
Engineering Development	59:24
Time-Sharing Development and Operation	64:02
Power Off	400:00
Miscellaneous (operating, tape rewind, tape skipping, tape mounting, rerun of failures, starts of time-sharing)	32:27

Total Use

Training and Education		9:31	
System Development		7:44	
Engineering Maintenance		13:12	
Customer Use			
In Systems	26:36		
Short Shots	:14		
Customer Use		26:50	
		Total Use	57:17
		Total Time	720:00

8.5.6.1.2 Summary of Machine Errors

April, 1967

Core	6
Tape Drives	5
Power Supplies	1
Paper Tape Punch	1
Air Conditioning	1
	14

May, 1967

Main Frame	1
Core	3
Channels	1
Tape Drives	3
Power Supply	3
Air Conditioning	2
Reader Punch	1
	14

June, 1967

Core	1
Flow Gating	1
Power Supplies	2
Disk File Control	1
Tape Drives	4
	9

8.5.6.1.3 Departmental Running Time

April, 1967

Department	No. of Runs			No. of Spec.			Time Used		
	Tr & Ed	Res	Total	Tr & Ed	Res	Total	Tr & Ed	Res	Total
AAE	68	42	110	6	3	9	1.045	1.540	2.585
AGE	14		14	1		1	.135		.135
CE	2	8	10	1	2	3	.005	.095	.100
CHE	153	6	159	2	1	3	1.496	.047	1.543
DCS	359	535	894	6	9	15	1.506	7.920	9.426
EE	151	71	222	7	3	10	.506	2.681	3.187
ENGH	14		14	1		1	.029		.029
MATH	62		62	1		1	.298		.298
MATRL		7	7		1	1		.202	.202
ME	74		74	7		7	.289		.289
MUSIC		10	10		1	1		.231	.231
NUCE	15	7	22	2	1	3	.088	.079	.167
PHYCS	18	11	29	2	3	5	.080	.124	.204
PHYX		1	1		1	1		.003	.003
TAM	21	24	45	1	3	4	.055	.361	.416
XSSS		29	29		1	1		.238	.238
SUB TOTAL	951	751	1702	37	29	66	5.532	13.521	19.053
DCSSYS		535	535		8	8		4.812	4.812
TOTAL	951	1286	2237	37	37	74	5.532	18.333	23.865

Tr & Ed = Training and Education

Res = Research

May, 1967

Department	No. of Runs			No. of Spec.			Time Used		
	Tr & Ed	Res	Total	Tr & Ed	Res	Total	Tr & Ed	Res	Total
AAE	214	105	319	7	5	12	3.527	5.132	8.659
AGE	11		11	1		1	.019		.019
AGEC		10	10		2	2		.084	.084
BEDRE		1	1		1	1		.001	.001
CE	13	1	14	1	1	2	.100	.001	.101
CHE	146	6	152	3	3	6	1.035	.078	1.113
DCS	392	886	1278	4	10	14	1.230	43.233	44.463
ED		2	2		1	1		.002	.002
EE	62	75	137	7	8	15	.147	1.507	1.654
ENGH	36		36	1		1	.111		.111
GENE	1		1	1		1	.001		.001
IE	25		25	1		1	.116		.116
MATH	34		34	1		1	.106		.106
MATRL		20	20		2	2		1.363	1.363
ME	167	14	181	11	1	12	.582	.149	.731
NHS		13	13		1	1		.061	.061
NUCE	57	14	71	3	3	6	.236	.117	.353
PHYCS	22	28	50	2	2	4	.118	.806	.924
PSYCH		2	2		1	1		.002	.002
SPCH		1	1		1	1		.001	.001
TAM	99	53	152	2	4	6	.527	.374	.901
XSSS		30	30		1	1		.109	.109
SUB TOTAL	1279	1261	2540	45	47	92	7.855	53.020	60.875
DCSSYS		662	662		9	9		12.194	12.194
TOTAL	1279	1923	3202	45	56	101	7.855	65.214	73.069

Tr & Ed = Training and Education

Res = Research

June, 1967

Department	No. of Runs			No. of Spec.			Time Used		
	Tr & Ed	Res	Total	Tr & Ed	Res	Total	Tr & Ed	Res	Total
AAE	124	96	220	2	6	8	7.108	1.679	8.787
CHE	9	58	67	1	3	4	.061	1.511	1.572
DCS	15	549	564	5	6	11	.065	5.926	5.991
EE	1	32	33	1	5	6	.001	1.709	1.710
MATH	10		10	1		1	.176		.176
MATRL		83	83		1	1		4.095	4.095
MMPE		1	1		1	1		.001	.001
MUSIC		35	35		1	1		1.314	1.314
NHS		3	3		1	1		.012	.012
NUCE	34	2	36	3	2	5	2.102	.050	2.152
PHYCS		17	17		4	4		.408	.408
TAM	2	11	13	1	1	2	.008	.292	.300
XSSS		41	41		1	1		.240	.240
SUB TOTAL	195	928	1123	14	32	46	9.521	17.237	26.758
DCSSYS		256	256		11	11		16.198	16.198
TOTAL	195	1184	1379	14	43	57	9.521	33.435	42.956

Tr & Ed = Training and Education

Res = Research

8.5.6.2 1401-III

8.5.6.2.1 Summary of Use

April, 1967

Scheduled Engineering	2:10
Unscheduled Engineering	6:15
Maintenance	:45
ILLIAC Preparation	118:40
Other (listing, autocoder, reproduce, cobol, operator training, load, SPS, etc.)	63:10
Power Off	400:00
Idle	129:00
Total	720:00

May, 1967

Scheduled Engineering	:30
Unscheduled Engineering	2:20
Maintenance	:45
ILLIAC Preparation	186:20
Other (listings, autocoder, reproduce, cobol, operator training, load, SPS, etc.)	44:00
Power Off	392:00
Idle	118:05
Total	744:00

June, 1967

Scheduled Engineering	9:05
Unscheduled Engineering	17:25
ILLIAC Preparation	139:15
Other (listing, autocoder, reproduce, cobol, operator training, load, SPS, etc.)	28:45
Power Off	400:00
Idle	125:30
Total	720:00

8.5.6.2.2 Summary of Machine Errors

April, 1967

1401 Main Frame	1
Card Read-Punch	1
Total	2

May, 1967

1401 Main Frame	1
1402 Reader Punch	1
1403 Printer	2
Total	4

June, 1967

1401 Main Frame	1
Total	1

9. IBM 7094/1401 SERVICE, USE, AND PROGRAM DEVELOPMENT

(Supported in part by the National Science Foundation under Grant No. NSF-GP-700.)

9.1 Log Summaries

Table I - IBM 1401-II

Summary of Use

April, 1967

Scheduled Engineering	:35
Unscheduled Engineering	10:07
Maintenance	4:15
7094 Preparation	548:02
List/Reproduce	22:26
Code Check	3:34
Tape Dump	5:08
Idle	51:36
Total	645:43

Table II - IBM 1401-II

Summary of Machine Errors

April, 1967

1402 Card Reader Punch	5
1403 Printer	1
Total	6

Table I - IBM 1401-IV

Summary of Use

April, 1967

Scheduled Engineering	1:00
Unscheduled Engineering	8:11
Maintenance	4:01
7094 Preparation	574:57
List/Reproduce	19:18
Code Check	3:47
Tape Dump	5:07
Idle	24:07
Total	640:28

Table II - IBM 1401-IV

Summary of Machine Errors

April, 1967

1401 Main Frame	1
1402 Card Reader Punch	1
1403 Printer	2
729V Tape Drives	1
Total	5

Table I - IBM 7094

Summary of Use

April, 1967

Scheduled Engineering				27:41
Unscheduled Engineering				3:26
Maintenance				11:47
Idle				12:01
Miscellaneous (Operator Training, tape rewind, system tape mounting, rerun of failing problems, tape skipping, destruction of clock reading)				112:22
Total Use				
Training and Education			81:52	
University Administrative Overhead Use			6:11	
System Modification and Improvement			12:36	
System Updating			9:08	
Customer Use				
In System		419:08		
Relinquish				
AGEC	1:05			
CE	:20			
GSBA	1:10			
Relinquish Total		2:35		
Special Short Shots		1:09		
Customer Use Total			422:52	
		Total Use		532:39
		Total Time On		699:56

Table II - IBM 7094

Summary of Machine Errors

April, 1967

1301 Disk		1
	Total	1

7094 Table III April, 1967

Dept[1]	Number of Runs			Number of Specs			7094 Usage in Hours-Minutes		
	T and E[2]	Res	Total	T and E[2]	Res	Total	T and E[2]	Res	Total
AAE	415	53	468	8	5	13	5 42.4	1 50.3	7 32.8
ACCY	38	96	134	1	3	4	5.3	1 51.0	1 56.3
ADV	0	4	4	0	1	1	0.0	2.6	2.6
AGE	115	399	514	4	10	14	1 12.2	6 37.0	7 49.3
AGEC	0	225	225	0	15	15	0.0	7 24.6	7 24.6
AGRON	49	141	190	1	10	11	25.7	2 47.9	3 13.6
ANS	0	226	226	0	5	5	0.0	3 20.6	3 20.6
ANTH	26	102	128	1	2	3	48.4	3 10.9	3 59.3
ASTR	0	229	229	0	6	6	0.0	3 32.0	3 32.0
BECBS	0	77	77	0	4	4	0.0	58.3	58.3
BINRE	0	53	53	0	1	1	0.0	14.3	14.3
BIOPH	0	22	22	0	1	1	0.0	9.1	9.1
CCDME	0	45	45	0	2	2	0.0	32.0	32.0
CCSCS	0	33	33	0	1	1	0.0	22.0	22.0
CE	561	1330	1891	12	44	56	3 14.5	37 6.5	40 21.1
CERE	29	0	29	2	0	2	9.2	0.0	9.2
CHE	667	2024	2691	7	49	56	6 9.8	56 7.1	62 17.0
CRC	0	23	23	0	1	1	0.0	20.8	20.8
DCS	1740	362	2102	5	14	19	10 53.9	5 56.9	16 50.9
DOW	0	6	6	0	1	1	0.0	3.1	3.1
DS	0	268	268	0	5	5	0.0	5 7.5	5 7.5
ECON	87	213	300	3	10	13	22.9	2 9.4	2 32.3
ED	0	147	147	0	7	7	0.0	3 22.0	3 22.0
EDPSY	70	6	76	1	1	2	56.1	1.5	57.7
EDTES	0	29	29	0	1	1	0.0	1 29.2	1 29.2
EE	2219	684	2903	10	23	33	8 7.1	10 38.5	18 45.7
ENGH	272	0	272	1	0	1	1 26.5	0.0	1 26.5
ENGLS	0	8	8	0	1	1	0.0	7.6	7.6
ENTOM	36	8	44	1	1	2	9.4	10.4	19.9
FOR	0	8	8	0	2	2	0.0	8.0	8.0
FT	0	7	7	0	1	1	0.0	2.3	2.3
GENE	67	26	93	3	1	4	21.1	8.9	30.1
GEOG	9	21	30	1	2	3	5.2	19.1	24.3
GEOL	70	43	113	1	2	3	33.2	17.8	51.1

Dept[1]	Number of Runs T adn E[2]	Res	Total	Number of Specs T and E[2]	Res	Total	7094 Usage in Hours-Minutes T and E[2]	Res	Total
GER	14	0	14	1	0	1	8.1	0.0	8.1
GSBA	190	67	257	3	2	5	4 35.6	1 24.0	5 59.7
HEC	0	11	11	0	3	3	0.0	23.8	23.8
HED	0	56	56	0	2	2	0.0	1 56.6	1 56.6
HORT	0	32	32	0	3	3	0.0	33.2	33.2
ICR	0	76	76	0	4	4	0.0	2 37.1	2 37.1
IE	205	0	205	2	0	2	1 46.1	0.0	1 46.1
IED	0	17	17	0	1	1	0.0	19.1	19.1
IGPA	0	7	7	0	1	1	0.0	3.9	3.9
ILR	0	82	82	0	1	1	0.0	32.1	32.1
INADM	0	16	16	0	3	3	0.0	9.5	9.5
IREC	0	115	115	0	3	3	0.0	3 16.1	3 16.1
ISEDA	0	2	2	0	1	1	0.0	1.0	1.0
LIBS	0	5	5	0	1	1	0.0	0.4	0.4
LING	0	5	5	0	1	1	0.0	2.8	2.8
MATH	4474	19	4493	3	1	4	14 59.0	4.3	15 3.4
MATRL	0	719	719	0	22	22	0.0	13 1.9	13 1.9
MCBIO	0	8	8	0	1	1	0.0	1.0	1.0
ME	1371	352	1723	17	20	37	11 35.9	3 39.0	15 15.0
MMPE	0	113	113	0	4	4	0.0	2 35.7	2 35.7
MUSIC	0	34	34	0	1	1	0.0	30.7	30.7
NHS	0	209	209	0	5	5	0.0	2 39.8	2 39.8
NUCE	131	453	584	4	14	18	1 16.0	7 24.4	8 40.4
OIR	0	299	299	0	1	1	0.0	4 17.8	4 17.8
PEM	0	184	184	0	6	6	0.0	1 49.0	1 49.0
PHYB	0	98	98	0	6	6	0.0	1 10.3	1 10.3
PHYCS	252	1114	1366	5	21	26	1 20.7	30 5.0	31 25.8
PHYSL	0	23	23	0	2	2	0.0	6.1	6.1
PHYX	0	2273	2273	0	11	11	0.0	151 18.8	151 18.8
POLS	0	34	34	0	4	4	0.0	1 55.0	1 55.0
PSYCH	142	854	996	3	27	30	39.3	13 48.0	14 27.4
REC	1	27	28	1	2	3	0.4	30.5	31.0
SCONS	0	119	119	0	1	1	0.0	1 37.0	1 37.0
SGS	0	35	35	0	1	1	0.0	27.3	27.3
SHCBR	0	13	13	0	1	1	0.0	2.3	2.3
SOC	72	10	82	1	3	4	44.9	12.4	57.3

7094 Table III April, 1967 Continued

Dept[1]	Number of Runs			Number of Specs			7094 Usage in Hours-Minutes		
	T and E[2]	Res	Total	T and E[2]	Res	Total	T and E[2]	Res	Total
SOCW	0	24	24	0	1	1	0.0	51.1	51.1
SPCH	0	1	1	0	1	1	0.0	5.3	5.3
SPED	0	104	104	0	2	2	0.0	2 1.4	2 1.4
SRL	0	5	5	0	1	1	0.0	3.3	3.3
SWS	0	224	224	0	16	16	0.0	3 6.1	3 6.1
TAM	433	329	762	10	14	24	4 1.3	5 54.2	9 55.6
VMS	0	5	5	0	1	1	0.0	0.8	0.8
VPH	0	7	7	0	1	1	0.0	7.9	7.9
VPP	0	41	41	0	1	1	0.0	11.2	11.2
VTED	0	35	35	0	3	3	0.0	38.6	38.6
WPGU	0	11	11	0	1	1	0.0	14.5	14.5
XSSS	0	235	235	0	1	1	0.0	1 8.6	1 8.6
ZOOL	0	414	414	0	6	6	0.0	3 19.2	3 19.2
Subtotal	13755	15834	29589	112	461	573	81 51.7	422 52.3	504 44.1
DCSSY[4]	0	665	665	0	21	21	0.0	12 36.0	12 36.0
XDCS[5]	0	77	77	0	1	1	0.0	9 7.6	9 7.6
SSUAD[6]	0	313	313	0	2	2	0.0	6 11.0	6 11.0
Total	13755	16889	30644	112	485	597	81 51.7	450 46.9	532 38.7

1 See list of departmental codes following
2 Training and Education
3 Special Short Shots
4 System Improvement and Modifications
5 System Updating
6 University Administrative Overhead Use

Table I - IBM 1401-II

Summary of Use

May, 1967

Scheduled Engineering		5:25
Unscheduled Engineering		9:42
Maintenance		6:01
7094 Preparation		551:34
List/Reproduce		3:08
Tape Dump		3:45
1604 Preparation		:10
Idle		46:54
	Total	640:35

Table II - IBM 1401-II

Summary of Machine Errors

May, 1967

1401 Main Frame		1
1402 Card Reader Punch		5
1403 Printer		1
	Total	7

Table I - IBM 1401-IV

Summary of Use

May, 1967

Scheduled Engineering	2:50
Unscheduled Engineering	4:50
Maintenance	4:45
7094 Preparation	576:15
List/Reproduce	28:44
Code Check	2:43
Tape Dump	:35
Idle	48:55
Total	669:37

Table II - IBM 1401-IV

Summary of Machine Errors

May, 1967

1403 Printer	3
1406 Core Storage	1
Total	4

Table I - IBM 7094

Summary of Use

May, 1967

Scheduled Engineering				16:06
Unscheduled Engineering				2:30
Maintenance				11:18
Tape Test (time used to test tapes when 7094 time clock is off)				9:27
Air Conditioning				2:55
Idle				5:14
Miscellaneous (Operator training, tape rewind, system tape mounting, rerun of failing problems, tape skipping, destruction of clock reading)				95:52
Total Use				
Training and Education			131:14	
University Administrative Overhead Use			5:43	
System Modification and Improvement			20:50	
System Updating			:33	
Customer Use				
In System		429:07		
Relinquish				
AGEC	2:20			
GSBA	2:23			
Relinquish Total		4:43		
Special Short Shots		:58		
Customer Use Total			434:48	
Total Use				593:08
Total Time On				736:30

Table II - IBM 7094

Summary of Machine Errors

May, 1967

Main Frame		1
Disk		1
Total		2

7094 Table III May, 1967

Dept[1]	Number of Runs			Number of Specs			7094 Usage in Hours-Minutes		
	T and E[2]	Res	Total	T and E[2]	Res	Total	T and E[2]	Res	Total
AAE	318	58	376	7	6	13	3 56.0	3 10.8	7 6.9
ACCY	69	74	143	1	3	4	26.8	2 4.9	2 31.7
ADV	0	3	3	0	1	1	0.0	3.9	3.9
AGE	120	147	267	2	10	12	1 22.0	1 57.2	3 19.3
AGEC	29	522	551	1	15	16	7.6	11 50.2	11 57.8
AGRON	5	138	143	1	13	14	3.5	1 34.4	1 38.0
ANS	0	164	164	0	6	6	0.0	1 37.9	1 37.9
ANTH	49	0	49	1	0	1	40.2	0.0	40.2
ASTR	0	169	169	0	7	7	0.0	3 32.8	3 32.8
BECBS	0	107	107	0	2	2	0.0	1 4.3	1 4.3
BEDRE	0	8	8	0	1	1	0.0	14.0	14.0
BINRE	0	51	51	0	1	1	0.0	12.5	12.5
BIOPH	0	4	4	0	1	1	0.0	3.7	3.7
CCCHE	0	1	1	0	1	1	0.0	5.2	5.2
CCDME	0	46	46	0	1	1	0.0	43.8	43.8
CCSCS	0	12	12	0	1	1	0.0	13.3	13.3
CE	1279	1077	2356	13	42	55	9 20.5	29 9.2	38 29.8
CHE	883	1929	2812	8	44	52	6 2.9	55 27.2	61 30.2
COMM	0	12	12	0	1	1	0.0	19.5	19.5
CRC	0	11	11	0	1	1	0.0	10.6	10.6
CURLA	0	3	3	0	1	1	0.0	3.9	3.9
DCS	994	582	1576	5	12	17	7 18.3	8 29.9	15 48.3
DOW	0	12	12	0	1	1	0.0	5.7	5.7
DS	0	263	263	0	6	6	0.0	4 48.3	4 48.3
DUE	0	14	14	0	1	1	0.0	16.2	16.2
ECON	332	433	765	3	12	15	2 40.4	5 25.2	8 5.6
ED	0	119	119	0	11	11	0.0	3 4.9	3 4.9
EDPSY	128	39	167	1	1	2	1 7.0	37.6	1 44.6
EDTES	0	31	31	0	1	1	0.0	54.8	54.8
EE	1060	703	1763	9	25	34	4 44.9	15 4.4	19 49.3
ENGH	219	0	219	1	0	1	1 32.2	0.0	1 32.2
ENGLS	0	4	4	0	1	1	0.0	1.4	1.4
ENTOM	18	7	25	1	1	2	4.6	1.9	6.5
FOR	0	18	18	0	3	3	0.0	14.8	14.8

Dept[1]	Number of Runs			Number of Specs			7094 Usage in Hours-Minutes		
	T and E[2]	Res	Total	T and E[2]	Res	Total	T and E[2]	Res	Total
FT	0	5	5	0	1	1	0.0	1.4	1.4
GENE	461	22	483	5	1	6	3.29.3	5.4	3 34.7
GEOG	0	18	18	0	2	2	0.0	4.9	4.9
GEOL	78	0	78	1	0	1	46.3	0.0	46.3
GER	15	0	15	1	0	1	5 10.4	0.0	5 10.4
GSBA	643	10	653	5	1	6	21 24.8	26.5	21 51.4
HEC	0	17	17	0	3	3	0.0	14.2	14.2
HED	0	24	24	0	2	2	0.0	31.3	31.3
HORT	0	28	28	0	3	3	0.0	31.9	31.9
ICR	0	167	167	0	3	3	0.0	6 50.0	6 50.0
IE	316	8	324	3	1	4	2 37.5	3.7	2 41.3
IED	0	6	6	0	1	1	0.0	5.2	5.2
IGPA	0	9	9	0	1	1	0.0	4.7	4.7
ILR	0	27	27	0	1	1	0.0	24.7	24.7
INADM	0	9	9	0	1	1	0.0	1.4	1.4
IREC	0	148	148	0	3	3	0.0	5 7.4	5 7.4
ISEDA	0	1	1	0	1	1	0.0	2.3	2.3
LIBS	0	9	9	0	3	3	0.0	13.1	13.1
LING	0	8	8	0	1	1	0.0	1.3	1.3
MATH	4533	18	4551	3	2	5	19 3.7	19.4	19 23.1
MATRL	0	559	559	0	22	22	0.0	9 32.0	9 32.0
MCBIO	0	17	17	0	1	1	0.0	4.8	4.8
ME	1985	362	2347	19	22	41	21 58.7	3 57.2	25 56.0
MKTG	0	6	6	0	2	2	0.0	6.4	6.4
MMPE	0	203	203	0	4	4	0.0	5 40.3	5 40.3
MUSIC	19	14	33	1	1	2	17.5	3.7	21.2
NHS	0	95	95	0	3	3	0.0	1 41.0	1 41.0
NUCE	185	684	869	5	16	21	2 7.9	13 45.7	15 53.7
OIR	0	313	313	0	1	1	0.0	5 24.1	5 24.1
PEM	0	193	193	0	8	8	0.0	2 1.3	2 1.3
PHYB	0	86	86	0	5	5	0.0	1 7.0	1 7.0
PHYCS	17	1048	1065	3	19	22	3.8	33 1.4	33 5.3
PHYPL	0	1	1	0	1	1	0.0	1.2	1.2
PHYSL	0	64	64	0	3	3	0.0	23.0	23.0
PHYX	0	1886	1886	0	10	10	0.0	143 59.4	143 59.4
POLS	34	43	77	2	7	9	1 18.6	1 50.2	3 8.8

Dept[1]	Number of Runs			Number of Specs			7094 Usage in Hours-Minutes		
	T and E[2]	Res	Total	T and E[2]	Res	Total	T and E[2]	Res	Total
PSYCH	222	909	1131	3	33	36	3 46.3	14 21.9	18 8.2
REC	40	21	61	1	2	3	23.5	8.4	31.9
SCONS	0	42	42	0	1	1	0.0	29.1	29.1
SCS	0	2	2	0	1	1	0.0	0.2	0.2
SGS	0	49	49	0	2	2	0.0	57.1	57.1
SHCBR	0	18	18	0	1	1	0.0	5.8	5.8
SOC	64	21	85	2	5	7	1 7.7	2 32.7	3 40.4
SOCW	0	25	25	0	1	1	0.0	1 15.4	1 15.4
SPCH	0	32	32	0	4	4	0.0	17.3	17.3
SPED	0	87	87	0	3	3	0.0	1 45.1	1 45.1
SWS	0	409	409	0	19	19	0.0	9 30.0	9 30.0
TAM	628	437	1065	10	17	27	8 9.4	7 59.2	16 8.6
VMS	0	2	2	0	1	1	0.0	0.4	0.4
VPP	0	28	28	0	1	1	0.0	9.5	9.5
VTED	0	40	40	0	3	3	0.0	43.4	43.4
WPGU	0	4	4	0	1	1	0.0	7.5	7.5
XSSS[3]	0	236	236	0	1	1	0.0	58.0	58.0
ZOOL	0	434	434	0	8	8	0.0	2 50.3	2 50.3
Subtotal	14743	15665	30408	118	493	611	131 13.7	434 49.0	566 0.1
DCSSY[4]	0	1009	1009	0	16	16	0.0	20 50.3	20 50.3
XDCS[5]	0	34	34	0	1	1	0.0	32.5	32.5
SSUAD[6]	0	291	291	0	1	1	0.0	5 42.5	5 42.5
Total	14743	16999	31742	118	511	629	131 13.7	461 54.3	593 8.1

1 See list of departmental codes following
2 Training and Education
3 Special Short Shots
4 System Improvement and Modifications
5 System Updating
6 University Administrative Overhead Use

Table I - IBM 1401-II

Summary of Use

June, 1967

Unscheduled Engineering		17:11
Maintenance		8:19
7094 Preparation		552:55
List/Reproduce		26:56
Code Check		1:31
Tape Dump		:06
ILLIAC II Preparation		1:10
Idle		56:51
	Total	664:59

Table II - IBM 1401-II

Summary of Machine Errors

June, 1967

1402 Card Reader Punch		6
1403 Printer		2
	Total	8

Table I - IBM 1401-IV

Summary of Use

June, 1967

Unscheduled Engineering		20:05
Maintenance		6:45
7094 Preparation		479:29
List/Reproduce		16:57
Code Check		1:08
Tape Dump		:26
Idle		53:28
	Total	578:18

Table II - IBM 1401-IV

Summary of Machine Errors

June, 1967

1401 Main Frame		1
1403 Printer		3
1406 Core Storage		1
729V Tape Drives		2
	Total	7

Table I - IBM 7094

Summary of Use

June, 1967

Scheduled Engineering				21:23
Unscheduled Engineering				42:49
Maintenance				10:09
Tape Test				5:48
Idle				15:59
Miscellaneous (Operator training, tape rewind, system tape mounting, rerun of failing problems, tape skipping, destruction of clock reading)				129:47
Total Use				
Training and Education			42:23	
University Administrative Overhead Use			7:08	
System Modification and Improvement			23:09	
System Updating			:18	
Customer Use				
In system		415:26		
Relinquish				
AGEC	4:30			
GSBA	:50			
Relinquish Total		5:20		
Special Short Shots		:21		
Customer Use Total			421:07	
Total Use				494:05
Total Time On				720:00

Table II - IBM 7094

Summary of Machine Errors

June, 1967

CPU Central Processing Unit	3
Disk	3
716 Printer	1
Tape Drive	3
CRT	1
721 Punch	2
Total	13

7094 Table III June, 1967

Dept[1]	Number of Runs			Number of Specs			7094 Usage in Hours-Minutes		
	T and E[2]	Res	Total	T and E[2]	Res	Total	T and E[2]	Res	Total
AAE	79	80	159	3	5	8	1 42.9	34.4	2 17.3
ACCY	0	68	68	0	3	3	0.0	47.9	47.9
ADV	0	24	24	0	2	2	0.0	1 16.0	1 16.0
AGE	2	205	207	2	6	8	2.3	3 12.1	3 14.5
AGEC	10	462	472	1	17	18	0.5	8 26.7	8 27.3
AGRON	26	97	123	1	11	12	4.3	1 54.0	1 58.4
ANS	0	214	214	0	6	6	0.0	2 53.0	2 53.0
ANTH	54	0	54	1	0	1	1 49.4	0.0	1 49.4
ASTR	0	92	92	0	5	5	0.0	1 19.1	1 19.1
BECBS	0	90	90	0	3	3	0.0	59.0	59.0
BEDRE	0	12	12	0	1	1	0.0	24.0	24.0
BINRE	0	68	68	0	1	1	0.0	24.9	24.9
BIOPH	0	12	12	0	1	1	0.0	3.8	3.8
CCDME	0	72	72	0	2	2	0.0	27.2	27.2
CCSCS	0	3	3	0	1	1	0.0	4.6	4.6
CE	198	1508	1706	11	45	56	1 33.5	45 43.4	47 16.9
CHE	257	1960	2217	4	46	50	2 7.1	62 53.8	65 1.0
COMM	0	49	49	0	3	3	0.0	2 23.5	2 23.5
CP	0	25	25	0	2	2	0.0	20.5	20.5
CRC	0	37	37	0	1	1	0.0	30.4	30.4
CURLA	0	2	2	0	1	1	0.0	2.7	2.7
DCS	650	227	877	7	14	21	2 34.6	6 33.4	9 8.0
DOW	0	29	29	0	1	1	0.0	48.7	48.7
DS	0	189	189	0	6	6	0.0	7 9.8	7 9.8
ECON	67	118	185	3	8	11	1 42.1	1 45.5	3 27.7
ED	0	174	174	0	10	10	0.0	5 38.8	5 38.8
EDPSY	96	5	101	2	1	3	2 12.4	3.2	2 15.7
EDTES	0	2	2	0	1	1	0.0	3.7	3.7
EE	62	593	655	6	25	31	1 11.3	10 30.8	11 42.2
ENGH	2	0	2	1	0	1	0.5	0.0	0.5
ENTOM	6	4	10	1	1	2	5.0	34.6	39.7
FIN	0	4	4	0	1	1	0.0	16.6	16.6
FOR	0	22	22	0	2	2	0.0	9.4	9.4
GENE	49	10	59	4	1	5	18.4	3.0	21.5

Dept[1]	Number of Runs			Number of Specs			7094 Usage in Hours-Minutes		
	T and E[2]	Res	Total	T and E[2]	Res	Total	T and E[2]	Res	Total
CEOL	42	23	65	1	2	3	1 5.6	42.1	1 47.8
GSBA	152	51	203	5	1	6	2 48.8	1 44.0	4 32.9
HEC	0	4	4	0	2	2	0.0	2.0	2.0
HED	0	81	81	0	1	1	0.0	3 44.9	3 44.9
HONOR	0	3	3	0	1	1	0.0	3.7	3.7
HORT	0	35	35	0	2	2	0.0	17.0	17.0
ICR	0	193	193	0	4	4	0.0	7 22.7	7 22.7
IE	21	0	21	2	0	2	7.3	0.0	7.3
IED	0	2	2	0	1	1	0.0	0.9	0.9
ILR	0	4	4	0	1	1	0.0	2.2	2.2
INADM	0	2	2	0	1	1	0.0	0.5	0.5
IREC	0	46	46	0	5	5	0.0	54.0	54.0
ISEDA	0	4	4	0	1	1	0.0	7.3	7.3
LIBS	0	4	4	0	2	2	0.0	26.8	26.8
MATH	29	34	63	3	2	5	33.1	1 15.0	1 48.1
MATRL	0	639	639	0	20	20	0.0	7 23.3	7 23.3
MCBIO	0	10	10	0	1	1	0.0	3.5	3.5
ME	458	369	827	12	17	29	12 44.0	4 55.4	17 39.5
MKTG	0	11	11	0	2	2	0.0	25.7	25.7
MMPE	0	181	181	0	5	5	0.0	2 21.4	2 21.4
MUSIC	15	62	77	1	1	2	23.3	1 23.4	1 46.8
NHS	0	156	156	0	2	2	0.0	3 48.2	3 48.2
NUCE	231	412	643	4	15	19	4 52.8	8 57.2	13 50.0
OIR	0	261	261	0	1	1	0.0	9 57.8	9 57.8
PEM	0	106	106	0	4	4	0.0	53.5	53.5
PHYB	0	98	98	0	5	5	0.0	57.1	57.1
PHYCS	0	1190	1190	0	21	21	0.0	42 10.1	42 10.1
PHYSL	0	83	83	0	3	3	0.0	20.0	20.0
PHYX	0	1595	1595	0	11	11	0.0	96 7.4	96 7.4
POLS	10	18	28	1	4	5	1 40.7	30.2	2 11.0
PSYCH	44	1113	1157	2	32	34	59.2	21 10.1	22 9.4
REC	0	48	48	0	3	3	0.0	1 31.8	1 31.8
SCONS	0	16	16	0	1	1	0.0	8.0	8.0
SCS	0	2	2	0	1	1	0.0	1.7	1.7
SGS	0	99	99	0	2	2	0.0	1 1.8	1 1.8
SOC	3	21	24	2	3	5	11.0	2 46.0	2 57.1

Dept[1]	Number of Runs			Number of Specs			7094 Usage in Hours-Minutes		
	T and E[2]	Res	Total	T and E[2]	Res	Total	T and E[2]	Res	Total
SOCW	0	63	63	0	3	3	0.0	3 23.1	3 23.1
SPCH	0	27	27	0	2	2	0.0	29.7	29.7
SPED	0	121	121	0	2	2	0.0	1 16.0	1 16.0
SRL	0	25	25	0	1	1	0.0	31.7	31.7
SWS	0	417	417	0	20	20	0.0	9 0.2	9 0.2
TAM	54	443	497	5	17	22	1 2.9	11 52.3	12 55.2
VMS	0	2	2	0	1	1	0.0	0.4	0.4
VPH	0	6	6	0	1	1	0.0	3.3	3.3
VPP	0	22	22	0	1	1	0.0	6.9	6.9
VTED	45	15	60	1	3	4	28.0	39.5	1 7.5
WPGU	0	16	16	0	1	1	0.0	5.4	5.4
XSSS[3]	0	73	73	0	1	1	0.0	20.8	20.8
ZOOL	0	131	131	0	8	8	0.0	1 18.1	1 18.1
Subtotal	2662	14794	17456	86	474	560	42 22.6	421 7.5	463 30.2
DCSSYS[4]	0	1528	1528	0	21	21	0.0	23 9.2	23 9.2
XDCS[5]	0	22	22	0	1	1	0.0	17.5	17.5
SSUAD[6]	0	304	304	0	1	1	0.0	7 7.7	7 7.7
Total	2662	16648	19310	86	497	583	42 22.6	451 41.9	494 4.6

1 See list of departmental codes following
2 Training and Education
3 Special Short Shots
4 System Improvement and Modifications
5 System Updating
6 University Administrative Overhead Use

10. PROBLEM SPECIFICATIONS

10.1 Research Problem Specifications

During the second quarter of 1967, 171 problem specifications were submitted to the department for computation. The following brief descriptions of these problems have been prepared for inclusion in this report by those submitting them. T indicates a calculation associated with a thesis.

2526-74001 T Economics. Determinants of Provincial-Municipal Expenditures in Canada. It planned to use regression methods in order to analyze Provincial-Municipal expenditures in Canada. Data will be garnered from Government of Canada publications: Financial Statistics of Provincial Governments and Financial Statistics of Municipal Governments. It is hoped that the results obtained will explain to some degree the determinants of provincial-municipal expenditures in Canada in the period 1951-61. (N. Michas)

2527-74002 T Library Science. The Effect of Arrangement on the Use of Library Catalogs. The purpose of this study is to test the theory that if there is a known level of effective use for a given library patron and a given type of catalog, certain changes in bibliographic entry, formatting, arrangement, etc., will yield a significant increase in that patron's effective use of the catalog. For this study, arrangement has been selected as the experimental variable. Comparison will be made between the results of a subject search using a divided catalog and an identical subject search using a dictionary catalog.

A question-problem instrument was constructed by randomly sampling the subject entries used in a dictionary catalog (at the University of Illinois). These were compared with the entries in a divided catalog (at the University of Wisconsin) and those that were in general agreement in all ways except arrangement were selected for the final test-instrument. Students were randomly sampled from the directories of the two respective schools and requested to complete the twelve-part search exercise. Responses were then scored and a mean "success ratio" computed for each student. The resulting scores will be tested for statistically significant differences by computing a t value for the difference of means for matched pairs. In addition, statistical analysis of the responses will be made to establish the

independence of such scores in respect to the patron's educational level, frequency of use of the catalog, and subject background by the use of factor analysis and multiple correlation. (James Krikelas)

2528-74003 Animal Science. Silage Evaluation Studies. The problem of evaluating silages without actually feeding them to animals and measuring their performance has been a hindrance to silage research. Due to space and animal number restrictions, only a few silage additives and their effects could be evaluated each year. This study has been designed to help overcome these problems. The first main objective is to find a faster and more efficient method of screening new silage additives. The second objective is to check these additives with actual feeding trials. The laboratory method of screening new silage additives will use 1 1/2 pint glass freezer jars in which various additives will be added to freshly chopped corn fodder and allowed to ensile. The resulting silages will be analyzed for pH, dry matter, volatile fatty acids, nitrogen, and lactic acid content. The feeding trials of new silages will involve recording of weight gains and carcass evaluation data of steers fed these silages. The data for both the chemical analysis and the feeding trials will be analyzed, after appropriate transformations, using the multiple regression program of the SSUPAC system. The measured characteristics, such as pH, dry matter, etc., will be dependent variables and the additives will be independent variables for the purpose of analysis. Significant regression coefficients for the additives will be used in evaluating which additives are important for both the glass jar silages and the feeding trials. (Condon)

2529-74004 Industrial Administration. Determining Leader Characteristics. It would be useful to businessmen if they could determine certain traits in individuals which are indicative of success in a given field. It is known that there are certain traits which are sufficient for success in a broad sense, but it would be helpful to determine if other traits are necessary and perhaps unique for success in a particular area of business. Data on 160 successful leaders in five fields have been collected using the Leadership Behavior Development Questionnaire. The criterion for success is monetary income. The factor analysis method used will be the Principal Axis method, and the Varimax Factor Rotation method will be used to obtain the meaningful factors. (James Elsesser)

2530-74005 Microbiology. Enzyme Kinetics. Kinetic parameters of several enzymes will be computed and statistically analyzed. The activity of enzymes as a function of concentration of substrate, coenzyme, and inhibitor will be estimated using chemical methods. The values obtained will be subjected to least squares regression analysis to determine which values should be discarded. The results, in terms of K_m (Michaelis-Menton constant, expressing the substrate concentration required for half-maximum velocity) and V_{max} (the maximum velocity) will be employed in attempts to define the characteristics of the enzyme active site. Subsequent similar analysis in the presence of certain competitive and non-competitive inhibitors will be used for finer analysis of the enzyme active site. Using enzymes from different biological sources and using enzymes which catalyze different reactions of the same substrate, further analysis of the enzyme active sites will be made to determine the relative degrees of homology between enzymes. (R. D. DeMoss)

2531-74006 T Health Education. A Survey of Football Injuries at Three Universities. This study is a descriptive survey of football injuries occurring at three universities. The injuries will be classified according to the area of the body involved, the type of injury, the position played by the injured player, his year in school and his skill, and the time in the season the injury occurred. Other variables to be investigated include whether the injury was a reinjury, and whether the injury occurred in a practice or in a game. The data are obtained from original injury records and transferred to Digitex data forms. Frequencies for each variable and selected intra-variable frequencies and percentages will be calculated. The Chi square test of significance will be used. The results will be used to examine trends in injury occurrence, to evaluate injury recording methods, and to determine the value of the information contained therein. (R. J. Moore)

2532-74008 Marketing. Some Correlates of Active Information Seeking. Experimental studies of active information seeking with particular relevance to consumer decision processes are to be conducted and evaluated. Among those variables whose effects will be studied are: cognitive need and style, positive and negative expectations, interpersonal need, ambiguity of content, conflict, and dissonance. Data will be obtained using student subjects under varying experimental conditions and will be evaluated statistically through the use of computer facilities. (Joel B. Cohen)

2533-74009 T Chemistry and Chemical Engineering. Self-Consistent Field Calculations. This problem will use as input atomic integrals obtained from another research program, and the molecular geometry and an initial set of eigenvectors to construct the Hamiltonian matrix for a molecule using the linear combination of atomic orbitals self-consistent field formalism of Roothaan. This matrix will then be diagonalized to give the eigenvalues and eigenvectors. The resulting eigenvectors will be compared to the initial set, and if they are not the same, will be used to form a new Hamiltonian matrix. The procedure will then be repeated until self consistency has been reached. (Donald Dugre)

2534-74010 T Chemistry and Chemical Engineering. Oscillations at a Fusion Front. Under certain conditions in the freezing of a liquid or in the melting of a solid, the interface tends to oscillate. A mathematical model describing the system will be attempted and the computer will be used to solve the equations involved (including the equations of motion and energy). The computer will then be used to compare these results with experimental results obtained through photographic and other techniques. (Walter Heitz)

2535-74011 T Physical Education for Men and Graduate PE. Effects of Number of Exercise Sessions Per Week on Certain Cardiovascular Variables. The purpose of this study is to contrast a two-day week with a four-day week running program, and to determine the effect of each on performance and cardiovascular parameters. The computer will be used to compute metabolic and fat data and to determine test-retest reliability coefficients for each test item. Means and variances will be compared using the t-test and analysis of covariance. (M. L. Pollock)

2536-74012 Physics Project X. DNA Degradation by X-Radiation. Using ultracentrifugation methods and radio isotope techniques, the molecular weight distributions of single and double stranded DNA molecules in mouse leukemic and bacterial cells x-irradiated with from 0 to 1000k rads have been obtained experimentally. The computer will be used to fit a model to these data in an effort to obtain a plot of the number of double and single strand breaks/cell as a function of the x-radiation dose. (Veatch)

2537-74015 T Educational Psychology. Staff Orientation and Elementary Counselor Trainees' Role Perceptions. A questionnaire containing items related to the role and functions of the elementary school counselor was administered to counselor trainees and staff of NDEA Counseling and Guidance Institutes in Arizona, Iowa, Oregon and Ohio. An analysis of the responses will be made to determine the amount of agreement between trainees and staff in their perceptions of the role and functions of the elementary school counselor. A second administration of the instrument to counselor trainees in these NDEA Institutes will be given to determine change in the students' perceptions of role and functions of the elementary school counselor. This second response from trainees will be compared with the staff perceptions to determine whether the change in students' perceptions have tended to become more or less congruent with those of the staff. In order to assess the agreement or congruence between student and staff perceptions, a frequency count and a factor analysis of the items will be made. (Alicia Tilley)

2538-74016 Electrical Engineering. BIOMATH. This specification number will be used for general computation in the areas of automata studies, cybernetics of large systems, and information processing in special systems. Specific areas under consideration include: enumeration problems in the theory of machines (e.g., counting of non-isomorphic directed graphs) and application of these techniques to problems concerning the topology of neutral nets; simulation studies of networks composed of a stochastic switching element (i.e., a switch which has a certain (preset) probability of being on at a particular instant in time); and the information processing characteristics of complex systems (networks composed of many (similar or identical) parts). (J. W. Atwood)

2539-74017 T Civil Engineering. Analysis of Thick-Walled Pressure Vessels with Openings. The objective of this research is the development of analytical techniques for predicting the structural behavior of a thick-walled pressure vessel with reinforced openings. The analysis of such structures involves the solution of extremely complex boundary value problems. The analysis technique that is to be employed approximates the true continuum structure with a finite element model. The degree of approximation can be decreased by making the finite element finer; and in the limit, the solution of the finite element approximation converges to the solution of the real continuum problem. The solution of the finite element model results in the numerical solution of large numbers of simultaneous equations. The computer is used to generate the necessary equations and perform logic operations and to modify the analysis procedures as the structure traverses various regions of behavior. The ability to cope with structural problems as complex as the analysis of thick-walled vessels with openings is possible only through the use of high speed digital computers. (E. P. Foster)

2540-74018 Civil Engineering. Cadweld Splices. Cadweld splices are used for splicing of reinforcing bars in reinforced concrete structures. Reinforcing bars so spliced exhibit different stress-strain characteristics than the bar itself. Generally the spliced bar undergoes larger deformations. Confinement of bars in concrete is expected to improve the stress-strain characteristics of the spliced bars. The object of this research project is to investigate the behavior of spliced bars containing Cadweld splices in the tension and compression zones of reinforced concrete columns and beams. The computer program will be used to obtain interaction diagrams for reinforced columns. (C. P. Siess)

2541-74019 English. Analysis of "A Midsummer's Night Dream." The object of this project is a literary analysis of Shakespeare's play "A Midsummer's Night Dream" using an approach based on the study of key words. These words are to be determined by making a concordance of the first words. Since it is a time consuming operation, the concordance will here be limited to the first act which, after a preliminary analysis, seems to present most of the main themes of the play. The key words will then be compared to the text of the play. The text will then be printed out, all the words being blanked out

except for the key words, which then appear on the printout in their original position. Two programs are being written in SNOBOL. One will accomplish concordance, the other comparison of the key words. It is hoped this objective approach to the study of a literary work will help the analyst in uncovering the basic structure and imagery of the play. (G. Treese)

2542-74020 State Water Survey. Statistical Analysis of Water Consumption. Water consumption data and data for thirty concomitant variables are tabulated for 1200 incorporated municipalities in Illinois. The study considers the principal factors affecting per capita consumption and relates the size of communities to their water consumption. Correlation, regression, factor, distribution, and X-Y plotting analysis techniques will be utilized to determine which factor or set of factors are pertinent in explaining water consumption variation. Empirical relations between water use and population will be developed. Analysis results will be useful in water resources planning for regions or for the entire State of Illinois. (Sandor Csallany)

2543-74021 Accountancy. Tables of Compound Interest. The development of a precise economic model of the operation of a large business entity requires precise planning by products, months, and operations over long periods of time. Such planning involves the use of precise compound interest calculation. Tables of these precise calculations are best developed by a computer. Specifically, the need is for: (1) an amount of 1 table for periods ranging from 1 through 50, with interest rates varying from 1/8%, 1/4%, 1/2%, 1%, 2%, 3%, 4%, 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50%; (2) a present value of 1 table for the same periods and interest rates as specified in (1); (3) an amount of an ordinary annuity table of 1 for the same periods and interest rates as specified in (1); and (4) a present value of an ordinary annuity table of 1 for the same periods and interest rates as specified in (1). (Norton M. Bedford)

2544-74022 Materials Research Laboratory. Strain-Amplitude Independent Part of the Internal Friction. Some years ago, the strain amplitude independent part of the internal friction was computed, assuming that the dislocation velocity is a linear function of the applied stress. But experimental results obtained at relatively low frequencies do not verify the predictions of this

model. On the other hand, experiments show that the dislocation velocity is not a linear function of the applied stress. The purpose of this work is to compute the strain-amplitude independent part of the internal friction, taking into account the function dislocation velocity versus applied stress, given by experiments. Then, predictions of this model shall be compared to experimental results. (Pierre Peguin)

2545-74023 T Electrical Engineering. Superdirective Helical Dipoles. The aim of the research is to investigate the use of small-diameter helices as elements in yagi-type arrays. High directivities are achieved by the use of such devices, and it is hoped that procedures will be developed for optimizing their performance. Approximate theoretical expressions will be developed for the radiation pattern and compared with experimental data. The computer results will be used to evaluate intermediate results, such as mutual impedance and current distribution, and to plot polar diagrams. (Hrair S. Cabayan)

2546-74024 T Civil Engineering. Dynamic Stability. The object of this project is to establish criteria of stability for an elastic column subject to a transient force pulse. The basis of the study is the direct method of Liapunov, which seeks to detect stability for a system directly from the set of differential equations representing the perturbed motion of the system without any knowledge of the solutions. The computer will be used to determine the trajectory of motion of a system of differential equations to test the stability criteria obtained in the analytical analysis. (S. Holzer)

2547-74025 T Theoretical and Applied Mechanics. Simulated Arterial Diseases. The computer will be used for research in the field of hemodynamics. Various abnormalities in the circulatory system alter the impedance characteristics of the arterial network. The computer will be used to determine the impedance changes in the network caused by a number of these abnormalities and by their placement in the system. Impedance predictions can be made theoretically by solving a series of first order algebraic equations. Since impedance is desired over a frequency range, this series of equations must be solved for each frequency. Data will be limited to a few system constants set by the

network geometry. In addition to solving this series of equations, data received from the heart pulse wave of a physiological specimen must be broken into its Fourier components. Computer results will be tabulated, graphed, and used for comparison with experimental results. (Sam Hawkes)

2546-74026 T Materials Research Laboratory. A Study of the Transformation Mechanism in Cobalt and Cobalt-Nickel Single Crystals by X-ray Diffraction Techniques. The Hexagonal Close Packed to Face Centered Cubic transformation in cobalt and cobalt-nickel single crystals is studied by X-ray diffraction techniques. The intrinsic, extrinsic, and growth fault probabilities, mean square strain, domain size, and stacking fault energies are evaluated from the peak shift and peak asymmetries. The experimental data are obtained with an X-ray diffractometer and counter set up. The peaks are recorded on a chart recorder while the ordinates are printed on a tape. These values will be transferred to IBM cards. The diffraction peaks are represented by Fourier series and the computer used for the determination of the Fourier coefficients, correction of the peaks for instrumental broadening by the Stokes method, and for the determination of the center of gravity of the peaks. These data will be used to propose a mechanism for the above HCP to FCC transformation. (M. S. Rashid)

2547-74027 Civil Engineering. Optimization with Probability of Failure as Constraint. The purpose of this study is to develop a method for the design of structural systems. In this study, the loads acting on the structure and the resistance characteristics of the materials of the members of the structure are all considered as random quantities. The geometry of the structure as well as the sectional properties of the members are assumed to be deterministic. A method of determining the probability of failure of structures is being developed. Design of the structure is based on the ideal that the members of the structure are proportioned in such a way that the weight of the structure is minimized and the specified probability of failure of the structure is used as a constraint condition. The contraint being a nonlinear function of the design parameters such as the sectional properties of the members of the structure, the problem is reduced to one of nonlinear programming techniques. (C. C. Tung)

2548-74028 T Electrical Engineering. Microwave Phase Shifter. This project includes the development of a varacter-controlled variable microwave phase shifter. The theoretical phase shift can be found by solving the characeristic equation of propagation in a corrugated wavequide for different frequencies and voltages. A transcendental equation will be solved by the method of Newton-Raphson. The computed data will be used to check the experimental results and plot calibration curves. (Hans Wiesenfarth)

2549-74029 Mechanical Engineering. Radiant Transfer Between Corrugated Surfaces. In another investigation, the influence of surface topography on the radiation properties of surfaces is being studied. With the availability of these properties, the radiant transfer and equilibrium temperatures for engineering surfaces may be evaluated. As a result, the influence of surface roughness topography on the radiant transfer may be studied. This study therefore provides one of the first investigations of the departure of engineering surfaces from the ideal surface models employed in common engineering analysis. The inclusion of surface topography effects in the surface properties results in a system of two simultaneous integral equations governing the heat transfer. These equations require numerical techniques for their solution. Standard numerical integration and interation methods are required to determine the appropriate solutions. (R. G. Hering)

2550-74030 Mechanical Engineering. Apparent Radiation Properties. The radiation properties of engineering materials are strongly influenced by surface topography. The purpose of this investigation is to evaluate the influence of surface roughness on the absorptance, emittance, and directional reflectance. An analysis has been completed to determine these effects, and the resulting governing relations are two simultaneous integral equations. The complexity of these equations requires that numerical techniques be used to ascertain their solution. Standard numerical integration methods and simple iterative techniques are necessary to determine the solutions. The solution of the governing integral equations is impractical without a high speed digital computer. (R. G. Hering)

2551-74031 Mechanical Engineering. Spectral Radiation Properties. An important aspect of the thermal radiation properties of engineering surfaces is their spectral or wave length dependence. A number of theoretical models for the wave length dependence have been suggested but none adequately investigated. It is the purpose of this investigation to ascertain the degree to which various models can describe the spectral properties of engineering materials. To investigate these models, experimental data are employed to ascertain certain fundamental properties of the material which are then used to evaluate the radiation properties from the models. These later results are then compared to the experimental data for the radiation properties. The digital computer is used to perform the numerical computations which may include numerical integrations using standard numerical methods. (R. G. Hering)

2552-74032 Mechanical Engineering. Radiant Transfer in a Space Environment. Radiation heat transfer between engineering surfaces in a space environment is being investigated. The purpose of the study is to develop methods of analysis which can yield a significant increase in the accuracy of prediction with simple models for the reflection and emission of radiation from engineering materials. For the system chosen for study, the radiant transfer is governed by two simultaneous integral equations the solution of which requires numerical techniques. These shall be solved using standard numerical integration techniques in conjunction with a method of successive approximations. The equations are of such a nature that the determination of their solution is impractical without a high speed digital computer. (R. G. Hering)

2553-74033 T Psychology. Factorization of the Stimulus-Response Scale. The aim of the present project is to establish the personality variables which, in theory, mediate external perceptiveness, defined as the ability to extract simple figures embedded within more complex ones, and internal perceptiveness, as measured by awareness of anxiety-producing stimuli. The data to be used are based on a series of pencil-and-paper tests administered to approximately 100 University of Illinois students. The ultimate goal is

to factor analyze this battery of tests and to extract three factors. A secondary goal is to obtain test-retest correlations for each of the variables as well as a linear regression of the internal perceptiveness variables on four selected measures of external perceptiveness. The computer results will be used primarily to isolate the most meaningful variables related to both internal and external perceptiveness. (Pieszko)

2554-74034 Agronomy. Research with Sudangrass. This research project involves testing new sundangrass hybrids for their possible use as a forage crop in Illinois. New hybrids are higher yielding and have lower prussic acid content. New hybrids are tested with present varieties with mean yields and analysis of variance calculated. The analysis of variance is used to determine significant differences among varieties and hybrids. Yield data will be collected for 3-4 cuttings. Data collected will be yield in tons/acre and prussic acid content. (Burger)

2555-74035 T Mechanical Engineering. Radiant Heat Transfer Between Non-Diffuse Surfaces. The general objective of this study is to evaluate the validity of some important simplifying assumptions employed in standard engineering calculations of radiant heat exchange between surfaces in the absence of a participating, intervening medium. Integral equations describing the radiant heat exchange for a simple, but representative, geometry have been formulated including the non-gray and directional nature of the radiant properties of engineering materials. These equations will be solved using standard numerical methods, and the results will be used to evaluate the approximate methods for the calculation of radiant heat exchange. (A. F. Houchens)

2556-74036 T Mechanical Engineering. Transient Conduction and Radiation. Simultaneous energy transport by conduction and radiation under time dependent conditions is under investigation. The analysis of a simple plane layer system yields the governing non-linear integro-differential equation. It appears that the only practical means of solving this equation is by high speed numerical computations on a digital computer. Standard numerical integration techniques and a method of successive approximations

are expected to be used to determine numerical solutions. The solutions will yield important technical information concerning the interaction of radiation and conduction in time dependent systems. (D. Doornink)

2557-74037 T Computer Science. Optimization of Resistive-Capacitive Networks. The standard resistive-capacitive networks used in traditional circuits are usually design for open-circuit loading and/or symmetrical components. Removal of these restrictions leads to a more complicated design theory, but can be expected to result in more useful transistor circuits in some cases. The present study will consider the bridged tee and the parallel tee. (Marcus L. Bunting)

2558-74038 T Computer Science. Functional Device Models in Circuit Design. Computer-aided circuit design programs such as ECAP and NET use equivalent circuits of various kinds to represent the active elements. While equivalent circuits are quite useful for hand calculations, other approaches may be more appropriate for computer programs. The present study is to investigate functional expressions to be introduced as subroutines. (Gary R. Guth)

2559-74039 T Civil Engineering. Structural Behavior of Prestressed Concrete Reactor Vessels. The objective of this research is the development of analytical techniques in predicting the behavior of prestressed reinforced concrete reactor vessels and establishing the limits of applicability of current theories. The analytical investigation will be conducted in parallel with an experimental investigation. The results of each phase will support the other, leading to the overall objective of a better understanding of the behavior of the prestressed concrete reactor vessel.

The analysis of such structures involves the solution of extremely complex boundary value problems. The analysis technique that is to be employed approximates the true continuum structure with a discrete model. The degree of approximation can be decreased by making the discrete model finer, and in the limit, the solution of the model converges to the solution of the real continuum problem. The solution of the discrete model results in the numerical solution of large numbers of simultaneous equations for which the computer is a necessary tool.

The computer is used to generate the necessary equations and perform logic operations to modify the analysis procedures as the structure traverses various regions of behavior. The ability to cope with structural problems as complex as a reactor vessel is only possible through the use of high speed digital computers. (A. Echeverria)

2560-74040 T Theoretical and Applied Mechanics. The Effect of Transverse Shear Deformation on the Bending of Circular Elastic Plates. A general solution for the title problem will be sought in the form of infinite trigonometric series and Bessel functions. The computer will be used to evaluate the general solution and/or to solve the set of six linear ordinary differential equations of Reissner using either Milne's method or the Runge-Kutta method. The classical thin plate solution to specific problems will be compared with the Reissner solutions. The computer will also be used to analyze data from an experimental three dimensional photoelastic study of the title problem. The data will be obtained using the "frozen stress" technique of photoelasticity. The results of this analysis will be used to make conclusions about the significance of considering the transverse shear stresses in the study of elastic plates. (T. F. Lehnhoff)

2561-74045 Bureau of Educational Research. Variables Associated with Teachers' Image of Research. The purposes of the study are to assess the image of educational research held by classroom teachers, the nature of their use of professional journals, and whether differences in image and use of professional journals are associated with selected personal and professional background variables. Data will be obtained from a selected sample of 300 public school teachers in East Central Illinois via a self-report instrument. Image of research will be measured in two ways: (1) a prepared multi-item scale; and (2) a form of the semantic differential. Items in the other two sections of the instrument will be used to obtain information about professional reading practices and personal and professional background variables. The Mann Whitney U test and the chi-square are the statistics to be used.

A pilot study is in progress to test parts of the instrument. The computer will be utilized to process data which have been transferred to key-punch cards. Printouts of certain of the data to test for scalability of the statements in the multi-item scale. The Varimax Rotated Factor Analysis

method will be employed to determine if the nine semantic-differential-type scales represent three distinct factors for the concept, educational research. A sample of 75 to 100 classroom teachers from two local systems are included in the pilot study. Assuming that the instrument adequately measures what it is designed to measure, selected statistical analyses tests will be performed on pilot data. (Fred D. Carver)

2562-74046 Economics. A Study of Teacher Backgrounds. Data from a questionnaire administered to some 500 secondary school teachers will be analyzed in the study. The major variables describe the social and economic characteristics of respondents' parents and the current professional status of respondents. The project will attempt to determine some relationships among these variables by tabular analysis and by non-parametric (or robust parametric) statistical analysis. SSUPAC programs will be used to prepare the tables and to compute the statistics. (M. Eugene Moyer)

2563-74047 Psychology. Graduate Prediction. This study involves the prediction of graduate school success as defined in terms of the various criteria which must be met throughout graduate school in order to obtain the Ph.D. The subjects for the study consist of all incoming graduate students in the Department of Psychology for the past three years. The predictors utilized involve: (1) the admissions criteria including the graduate record exam verbal and quantitative scores as well as various undergraduate indices; (2) peer ratings of achievement, aptitude, and personological characteristics; (3) self-ratings on an empirically constructed instrument designed to measure interests, abilities, and motivational characteristics; (4) various demographic characteristics. The analyses include obtaining a variety of descriptive statistics (means, variances, correlations, etc.) both within and across the psychology department divisions. Further, a double cross-validation design involves obtaining regression weights on the basis of one sample and cross-validating these weights on a second, similar sample. In addition, various multivariate techniques will be utilized such as factor analyses, canonical correlations, and multiple discriminate functions. The over-all aim of the present study is to provide a "best set" of predictors for graduate school success which

will enable an evaluation of the graduate school criteria for obtaining the Ph.D. in psychology. (Wiggins)

2564-74048 Honors. Perceptual Changes of Honors Students at the University of Illinois. The purpose of this study is to investigate the changing perceptions of James Scholars toward the University of Illinois and the related implications these have for modification of the institutional mileau. The primary instrument to be used to measure the perceptual changes of four entering classes of James Scholars (1967-1970) will be The College Characteristics Index, developed by George G. Stern and C. R. Pace at Syracuse University. In addition to studying the relationship of the variables of this instrument and mileau factors, development of scales particular to this group and institution will also be attempted. The forseeable use of the computer will be for correlations, item analyses, factor analyses, variance analyses, and covariant analyses. (M. Jean Phillips)

2565-74049 Chemistry and Chemical Engineering. Hydrogen Molecule Terms. The terms (i.e., energies of excited electronic states) of the hydrogen molecule are of great importance in spectroscopy. It would be desirable to know not only their energies, from which frequencies of the spectroscopic transitions could be calculated, but also their wavefunctions, which can be used for the prediction of intensities. Most quantum chemical calculations focus on the ground electronic states of systems. It is not clear whether the conventional techniques will be equally applicable to excited states. It is expected to try the variational technique, where the nth root of a secular equation is an upper bound to the nth true energy (of a given symmetry). In addition, perturbation theory seems promising. Here, one solves the first-order Rayleigh-Schrödinger perturbation equation by a variational technique. Finally, the minimization of the width technique of Weinstein will be used. The integrals necessary for these calculations will be done numerically, by Gauss or other techniques. Available routines for Schmidt orthogonalization, matrix eigenvalues, and other matrix manipulations will be used. (Jerry Goodisman)

2566-74050 T Communications. Effects of Campaign Communications. In 1962 a study was made of the attitudes of the Champaign-Urbana electorate towards two congressional candidates. Included in this study was a survey of the mass media consumption of that electorate. These data have never been analyzed in relation to the political attitudes held. This study intends to explore that relationship in an attempt to test the generally held belief that campaign propaganda has little direct effect on political attitudes. This study will use three hundred interviews containing one hundred fifty variables. The analyses of these will be done by analysis of variance, factor analysis, and correlational techniques. The results of these analyses will be used to test for sensitization, learning over time, and the interaction of beliefs and attitudes with crosspressure and various modes of media consumption. (Colldeweih)

2567-74051 Dean of Women. Some Factors Correlated to Low Achievement in Freshman Women. Data have been obtained from the files and records of the Dean of Women's Office, Admissions Office, Student Counseling Service, Student Loan Office, and the Student Employment Office. The data include scores on the American College Test and the Freshman Guidance Exam. The initial use of the computer will be the cross tabulation of variables to determine what further statistical analyses are appropriate. The results will be used to describe and make generalizations about low academic achievement in a group of 400 freshman women in Liberal Arts and Sciences. The population was selected on the basis of expected high ability as indicated by an average of the composite test score on the American College Test and the percentile rank in the high school graduating class. (Aletta Ellicott)

2568-74052 T Chemistry and Chemical Engineering. Investigation of the Trans Effect. This research concerns investigating the theoretical basis for the "trans effect" which plays an important part in the chemistry of square planar compounds, particularly those of platinum. The investigation is to be carried out by means of molecular orbital calculations on square planar complexes of platinum. The techniques to be used are those standard to molecular orbital calculations, i.e., the calculation of the eigenvalues and eigenvectors of the system by diagonalization of the Hamiltonian matrix. The matrix diagonalization is done by the Jacobi method. (S. Zumdahl)

2569-74053 Political Science. Political Community and the Electorate. This research project is designed to explore the way in which the American voter is conditioned by the form and style of politics most immediate to him. The proposed study seeks to discover how electoral behavior and attitudes are correlated with structural and competitive features of local political systems. Approximately thirty cities and counties in the United States provide the units of analysis for the study. Each locality will be identified on the following dimensions: (a) whether the form of local government is partisan or non-partisan (b) whether the locality can be described as having a strong or weak party organization; and (c) the degree of competition. Presently, data have been collected from the above mentioned units. The next step is to correlate the variables which have been isolated in an effort to find meaningful relationships between certain political variables. (M. Weinbaum)

2570-74054 Agronomy. Fatty Acid Study in Soybeans. The five major fatty acids in soybeans are palmitic, stearic, oleic, linoleic, and linolenic acids. Recent studies indicate that linolenic acid causes rancidity and is the source of undesirable odors in soybean oil. The purpose of this study is to investigate the inheritance pattern of the five fatty acids. Data on specific fatty acid content have been obtained by gas chromatography, and data on total oil content by nuclear magnetic resonance, for 222 soybean crosses involving several generations of breeding material. In order to estimate the correlation coefficients among the fatty acids, and to estimate the correlation between individual fatty acids and total oil content, the data will be subjected to correlation analysis on the computer. The results of this analysis will help in determining the inheritance pattern, and perhaps indicate to plant breeders possible methods of selection for either high or low content of specific fatty acids. (Hadley)

2571-74056 T Theoretical and Applied Mechanics. Stress Analysis of a Heated Disc. An investigation is being made to determine stresses in a thermally cycled steel disc. Two factors which complicate the analysis are unsteady-state heat transfer and inelastic behavior. The temperature distribution in the specimen during heating will be found by using a finite difference approximation of the equation of heat-conduction. The temperature distribution will be used with an iterative procedure to find the stress distribution in the disc. When

yielding of the material occurs, the total strain theory of Hencky will be used to relate stress and strain. Residual stresses found analytically will be compared with those measured in actual test specimens. (T. R. Simovich)

2572-74057 Computer Science. Compiler Generation System. This research work involves both the modification and improvement of a previously designed table driven syntactic analyzer and the design of a table processor and operating system to allow this device to be used to translate the ILLIAC IV compiler language. A well-designed compiler generation system can greatly reduce the time and effort required to write a compiler for a given language. It also allows the compiler to be easily modified to reflect changes in the input language, in the target machine (ILLIAC IV), or to incorporate code optimization algorithms. (R. E. Marks)

2573-74058 Physical Plant. Correlation of Janitor Civil Service Test Score and Evaluations of Performance and Age. There has been considerable controversy on the relationship of the janitor Civil Service score with later work performance. An attempt is being made to correlate the following: (a) Civil Service score with Final Certification Evaluation; (b) Civil Service score with Current Evaluation; (c) Age and current evaluation; (d) Final Certification Evaluation and Current Evaluation. This program may validate the existing Civil Service examination, or if not, it could indicate points for improvement and subsequent validation. (Jack T. Harroun)

2574-74059 Civil Engineering. Turbulent Open Channel Flow Study. The classical ultramicroscopic approach has been modified and developed for the determination of velocities within the viscous sublayer in open channel flow. The technique consists essentially of using a high-power microscope and dark-field illumination to observe the movement of small neutrally buoyant spheres suspended in the flow. High speed photography permits the determination of the velocity of the spheres within the small optical depth of field. A preliminary study of laminar flow has been completed. Two dimensional turbulent flow is being studied. Tractive force and turbulence data will be obtained and analyzed. This method is particularly adaptable for obtaining measurements

near the boundary since no probe is placed in the flow. The particles have a small response time and hence act as valid tracers for turbulence measurements. After the two-dimensional study is completed a narrow open channel will be investigated in which three-dimensional effects will be present. (H. G. Wenzel)

2575-74060 T Theoretical and Applied Mechanics. Buckling of Orthotropic Plates. The problem to be solved is that of buckling of generally orthotropic plates with various applied loads and boundary conditions. The analysis is based on the second variation method of energy methods. The Lagrange multiplier technique is used to find the minimum of a function of several variables subjected to side constraints. The computer will be used to find roots of determinates in order to obtain upper and lower bounds of the buckling load. (H. R. Fraser)

2576-74061 Civil Engineering. Weber Criterion. In small hydraulic models no criterion is available to delineate the scale at which surface tension effects become predominant. Tests of small scale models of spillways are commonly transferred to much larger prototype structures utilizing the Froude Law and neglecting the effects of surface tension and viscosity. The lower scale limit for such models is determined by past experience rather than by the application of a scientifically determined criterion. An experimental investigation to delineate critical lower values of the Reynolds and Weber numbers is being undertaken. A modified definition of the Weber number is being investigated in the hope that the critical Weber number established will be independent of geometrical configuration. The experimental program involves the collection of data for a variety of vertical channel obstructions at low flow rates, using surface tension reducing additives. The computer will be used to reduce effort on routine computations in the data analysis, to design an experimental procedure which will minimize errors, to investigate several methods of defining the Weber number, and to generate isovel patterns based on velocity traverses. (W. H. C. Maxwell)

2577-74062 T Chemistry and Chemical Engineering. Flow Through Regular Packed Beds. The subject of this investigation is the prediction of mass transfer coefficient and shear stress distribution on the surface of a sphere in a regular packed bed for Stokesian flow. Snyder (1965) solved the Navier-Stokes equations with boundary conditions appropriate for rhombohedral

packing and obtained analytical expressions for the velocity profile (3 components) by using the so-called "projection methods" (more specifically the Galerkin's method). Starting from these expressions the stress vector T can be calculated, i.e.,

$$T=(\partial u/\partial n)i+(\partial v/\partial n)j+(\partial w/\partial n)k$$

by taking the derivatives of U(u,v,w) in the direction (n) normal to the surface of the sphere. The component of T, T_w, tangent to the surface at some point constitutes the shear stress due to viscous effects. The direction of the component T_w must be also calculated. The obtained shear stress distribution enables us to determine "strips" on the spherical surface confined between lines across which the shear stress T_w is the same direction. On such "strips" the mass transfer equation can be solved by making some simplifying assumptions (Lighthill, 1950) and the local mass transfer coefficient can be calculated. (Anastasius Karabelas)

2578-74063 Economics. Dividend Policies of Firms. This study will empirically test the Modigliani-Miller hypothesis that changes in the dividend policies of a firm do not affect the value of a firm. A simulation analysis will be used to examine the consequences of changes in the payout policies of twenty firms upon the values of the firms. Data on twenty public utility companies were taken from Moody's Public Utility Manual. The computer will be utilized to simulate the effects of changes in the dividend distribution policies of the twenty firms on dividends and common stock prices from 1950 to 1965. Mathematical methods to be used will include the simulation analysis and elementary operations on matrices whose rows will represent data for the companies in years represented by the columns of the matrices. A substantial difference between the values of the actual and simulated firms will invalidate the Modigliani-Miller hypothesis. (C. E. Richter)

2579-74065 T Zoology. Quantitative Analysis of an Odontometric Trait in Mice. Most higher organisms possess traits which are of the continuously varying type, that is, they are quantitative. Such traits may be studied in terms of their variability as measured by their variance. Such variance is normally partitioned into a series of casual components, some genetic and some environmental in origin

Both theoretical and practical applications can be made from information relative to the percentage contribution to the total variance of each of the various components. In this analysis, measurements have been taken in microns of the second and third mandibular molars of two species of mice. A so-called diallel analysis is to be used in estimating the various components of variation in seven inbred lines of the house mouse. Essentially, the analysis consists of forming a series of simultaneous equations involving the unknown components as expressed in a complex linear model, and then solving them by the formation and manipulation of matrices. Constant estimates, various correlations between the variables, and the analysis of variance complete with F tests will all be printed out by the computer. A standard regression analysis will be used with the other species, essentially comparing parents and their offspring in order to estimate a quantity known as the heritability, this being the percentage of the total variance which is due to the additive effects of genes. Interpretation of the importance and role of the various components which are significant may then be made. (Larry J. Leamy)

2580-74066 T Psychology. Vietnam Attitude Research. This research deals with attitudes toward American participation in the war in Vietnam, on the basis of attitudes toward means employed and outcomes expected. The data were collected by administering a specially constructed attitude scale to 200 female subjects enrolled in the introductory psychology course. They include correlation, t test, and analyses of variance. The computer will be used to reduce data to readable form (i.e., means, standard deviations) and to compute tests of statistical significance. (Arthur R. Carlson)

2581-74067 Agricultural Economics. Factors Influencing Chicago Egg Prices. How well egg prices reported from the Chicago market (and used to price eggs at many points throughout the Midwest) reflect actual supply and demand conditions for eggs has been questioned. Multiple regression analysis will be used to measure the extent to which changes in egg prices reflect changes in existing supply and demand factors for eggs. Spatial equilibrium analysis will be used to ascertain the equilibrium prices of eggs in various areas of the United States and the anticipated movement of eggs between areas. These data will be compared with reported price differences between areas and reported flows of eggs between areas. (J. R. Roush)

2582-75001 Computer Science. Diffraction Pattern Analysis. The purpose of this project is to analyze various diffraction patterns of laser beams which have a Gaussian wavefront. The analytic solution contains complex error functions whose roots are to be solved numerically. The error functions can be expanded into a series form, and the roots of real and imaginary parts can be solved numerically by Newton's method. The computer results will be used to compare with the experimental data. (Tuh-Kai Koo)

2583-75002 Aeronautical and Astronautical Engineering. Theoretical Optimization of Non-Isoenergetic Ejectors. Gas dynamic equations are used to compute the performance and optimum geometry of a single ejector stage. Using a mathematical model to represent the ejector performance one can evaluate the derivatives in the optimization equations. An iteration procedure is used to solve the N + 1 interdependent equations for the N stage ejector system. (J. L. Loth)

2584-75004 Materials Research Laboratory. Pressure Effect on Self-Diffusion in Titanium. Self-diffusion in beta-phase titanium is studied using temperature and pressure as parameters. The calculation involves making a least-squares fit to a straight line of points on a semi-logarithmic plot of specimen radio-active counting rate versus penetration distance squared. The data are obtained by depositing a thin layer of radio-active tracer, titanium-44, onto the surface of the titanium specimen. At high temperature the tracer diffuses into the specimen; the pressure is fixed for a particular run but is varied from run to run to determine the pressure effect. The specimen is sectioned in a precision lathe, the thin layers thus removed are weighed, and their radio-activity is determined. The specific activity and the penetration distance of each section constitute the data. (Rondo N. Jeffery)

2585-75005 Library Science. Analysis of North Country Survey. A survey of the potential role of libraries in the North Country area in New York's proposed 3-R program, sponsored by the North Country Reference and Research Resources Council, was conducted by the Library Research Center, 1965-66. A supplementary analysis of the responses to a faculty use questionnaire is

being undertaken to determine the characteristics of use in the State University Colleges at Potsdam and Plattsburgh. The responses will be tabulated to provide frequency counts on frequency of use, rating of the quality of the book collection, other resources used, a rating of the physical qualities of the libraries, the effects on teaching methods, and plans for future courses that may requre stronger library resources. In addition, certain measures of associations will be described using chi-square to test for statistical significance. (Guy Garrison)

2586-75006 T Theoretical and Applied Mechanics. Interaction Between Edge Dislocations and a Surface Layer. The interactions between edge dislocations in the interior of a crystal and a finite surface layer are being investigated. For the case of a single edge dislocation, the interaction force involves certain infinite integrals which require numerical results for interpretation. The interaction of several dislocations with the surface layer is more complex, resulting in integral equations which must be inverted numerically. For both the single dislocation and the pile-up problem, results for various combinations of surface layers and substrates will be investigated. (Richard W. Weeks II)

2587-75007 Agronomy. Soybean Breeding Methods. Yields of soybeans seem to have reached a threshold level. To break this yield barrier plant breeders are interested in finding new genotypes with higher yielding potential. The procedure involves the crossing or hybridizing of pureline material and subjecting the progeny to reproduction by self-fertilization. The plant breeder must decide whether to evaluate subsequent generators by the traditional plant to row pedigree system, or by compromise system such as early generation testing of the progeny of the original crosses. The purpose of the present study is to evaluate the above three breeding methods as to their effectiveness in locating high yielding genotypes. A number of field experiments will be conducted. Statistical analysis will be performed on the computer to allow scund comparisons of the methods to be made. (Cooper)

2588-75008 T Physiology. Tracer Fluxes Across Cell Membranes. The proposed research involves the measurement of ionic fluxes across the membranes of intestinal smooth muscle cells. The fluxes are followed by using the radioactive isotope of that particular ion. The count data will be corrected for decay, time of count, and dead time of the detector-scaler system by means of a computer program already being successfully used for Na^{24} and K^{42}. In addition, the corrected count data will be plotted roughly on the same print-out sheet as a function of time. During a period of the washout curve of the muscle, fractions of isotope will be collected during one cycle of an electrically recorded "slow wave". These fractions will be counted and corrected by the computer. A graph of these counts per minute versus the fraction number will be plotted. Both graphs will be replotted with greater accuracy using the CalComp Plot program. The computer will also be used in the development of a theoretical model for the origin of these "slow waves", building up a summated curve from the flux patterns of the individual ion fluxes observed. (Don D. Job)

2589-75009 T Mining, Metallurgy, and Petroleum Engineering. River Networks. The problem deals with quantitative land form analysis as it applies to normally developed hydrographic basins in which running water is the chief agent in developing surface geometry. Quantitative physiographic factors such as stream order, bifurcation ratio, and channel frequency will be defined and some of their properties will be examined using the Wabash basin as a test case. Data have been supplied by the Division of Water Supply and Pollution Control, U. S. Public Health Service. This information will also be used to test the accuracy of the law of stream numbers, which states that the numbers of stream segments of each order form an inverse geometric progression with order number. Furthermore, considering river nets as the outcome of a stochastic branching process, graph theory will be applied to drainage basins. The basic statistical assumption that all possible graphs (i.e., arborescences with a given number of pendant vertices) are equally likely to occur will be tested using the same data. The problem involves storage of large amounts of information, and repeated calculations of the same set of theoretical formulas using different numerical data. The results will provide more information on the linear aspects of river nets. (Thakur R. Tukrel)

2590-75010 T Sociology. Effects of Community Variables Upon Police Release Ratios. A multivariate analysis of community variables related to police release ratios with juveniles will be made. Initial analysis will be in terms of a cross tabulation. The community variables were obtained from the 1960 census. These variables include data from specific urban areas on population, youth under eighteen, percentage non-white, region, income, educational levels, mobility indices, and percentage foreign born. Data on the dependent variable, police release ratios for juveniles, were obtained from the Federal Bureau of Investigation on 2,367 police agencies serving the specific community on which census data were gathered. These two sources of data will then be matched and contrasted to find the effects of certain community characteristics upon the police agency's release behavior with juveniles. Various controlling techniques will be used to separate the influence of each varied factor upon the dependent variable. (Robert E. Ford)

2591-75011 Division of University Extension. Management Training Evaluation. This study concerns an evaluation of a four-year Management Development Program conducted since 1957 by the Division of University Extension. Supervisory ability, intelligence, personality charactersitics, and other data were obtained through the administration of tests to the program participants. Information on various characteristics of the participating groups will be determined. Correlations between supervisory ability and other factors will be obtained. (Harold Wecke)

2592-75012 Electrical Engineering. Statz-De Mars Equations for a Helium-Neon Laser. The Statz-De Mars equations describe the build-up of oscillations in lasers. For a typical helium-neon laster these equations are:

$$\frac{dN}{dt} = 1.35 \times 10^{16} - 2.22 \times 10^{-2} NS - 10^{7} N$$

$$\frac{dS}{dt} = 2.22 \times 10^{-2} NS - 6 \times 10^{6} S + 2.22 \times 10^{-2} N$$

where N is the population inversion and S is the number of photons per mode of oscillation. The coefficients describe the type of laser used and depend on

various physical parameters. This problem will study the effect of varying these parameters with and without respect to time. The Runge-Kutta method for first order differential equations will be used to obtain the solutions. (V. J. Monty)

2593-75013 T Civil Engineering. Missile Silo Closure Analysis. The prototype problem is a thick, reinforced concrete plate forming the closure for a missile silo which may be exposed to air overpressures of several thousands of pounds per square inch from an attacking nuclear weapon. The plate is supported over an annular area with outside radius coinciding with that of the closure. The prototype loading is produced by the traveling wave from a nuclear burst, and varies in space and time. The objective of the research is to derive a method for designing such a closure to deform inelastically, within acceptable limits, under the assumed loading. The mathematical model will be developed in three stages. In all stages, an axisymmetric loading and a homogeneous, isotropic material will be assumed. The first stage will consider linearly elastic behavior under a static load. Stage two will permit inelastic deformation with a static load. The last stage will consider time-dependent loading. The plate will be represented as an assembled group of discrete elements joined at common vertices. Stiffness matrices for the individual elements will be computed and superposed to form the coefficients of the system of equilibrium equations for the structure. These will be solved by a Gauss-elimination procedure (in the static case) to determine displacements of the element vertices. Maximum use will be made of the sparseness of the coefficient matrix to reduce processing time and core storage requirements. The computer results, consisting of stress, strain, and displacement data will be used to predict model behavior in a concurrent laboratory test program. (Robert M. Iten)

2594-75014 T Aeronautical and Astronautical Engineering. An Error Analysis of Molecular Beam Experiments. Measurement accuracy in molecular beam experiments is limited by the transducer system and the overall geometrical arrangement of the apparatus. The present work analytically determines upper bounds of the error due to the geometrical constraints. The resulting expressions are evaluated using the Department of Computer Science facilities

for various combinations of apparatus parameters to establish optimization criteria for apparatus design. Specifically, the computing facilities are used to evaluate complex algebraic expressions of error magnitudes. These numerical results then determine the choice of apparatus parameters from one stage of the analysis to the next. (A. Klavins)

2595-75015 Electrical Engineering. Ionospheric Research Using Groundbased Techniques. The Aeronomic Laboratory of the Department of Electrical Engineering is currently carrying out routine groundbased experiments at a nearby field site. In one of these experiments, circularly polarized radio frequency waves will be transmitted vertically upwards using an extensive aerial system spread over twenty acres of land. The relative amplitudes and phases of the partially reflected signals from the lower ionosphere on the two magneto-ionic components will be received on an equally large antenna array and will be recorded as a function of altitude. The information will be used to deduce the electron number density profile as well as the collision frequency of electrons with neutral particles as a function of altitude. Computer facilities will be used to solve complicated generalized magneto-ionic formulas and for averaging several bits of information to form a consistent picture of the lower ionosphere.

In another experiment the movements of electron clouds in the ionosphere will be determined by using groundbased transmission of radio waves and by deducing the auto and cross correlation functions of amplitude fading records received at several locations on the ground. Also studied, using these measurements, will be the scale sizes, axial ratios, tilt angles, etc., of the irregularities causing the fading of the received signals.
(S. A. Bowhill)

2596-75017 Chemistry and Chemical Engineering. Polymer Dimensions and Hydrodynamics. This problem is concerned with calculation of dimensions and hydrodynamic properties of polymer chains. Polymer dimensional statistics for real chains without excluded volume are to be calculated according to Ising matrix methods as developed by Flory for hydrocarbons, polyamino acids, and polynucleotides. Some excluded volume calculations, using Monte Carlo-generated random walks, will also be done for relatively short chains. The object of these calculations is to obtain dimensional statistics for quantities other than the mean-square end-to-end distance, such as the mean reciprocal

distance between chain elements. These values are needed for subsequent calculation of hydrodynamic properties. Intrinsic viscosity, sedimentation and diffusion coefficients, and rotational frictional coefficients for a variety of biologically interesting polymers, including those mentioned above and polysomes and viruses as well, will be calculated using the dimensional statistics arrived at previously. (Victor Bloomfield)

2597-75018 T Electrical Engineering. Heat Exchange Processes Between the Ionosphere and the Protonosphere. A number of satellite and ground-based experiments have established the fact that electron temperatures in the region above 140 km are substantially higher than the temperatures of the positive ions and neutral constituents of the atmosphere. The temperature of the neutral constituents approaches very quickly an asymptote far below the temperature of the electrons. The ion temperature is initially the same as that of the neutrals but approaches the electron temperature at high altitudes. Electron temperature profiles based on backscatter data show a positive electron temperature gradient at high altitudes in a region where theory predicts isothermal behavior. For a positive temperature gradient to be maintained when the thermal conductivity of the electrons is high a substantial heat source is required. It has been proposed that the protonosphere provides such a source. The theoretical and experimental electron temperature profiles differ also at low altitudes. The experimental curves are lower than the theoretical ones and decrease rapidly with decreasing altitudes between 300 and 200 km where the theoretical temperatures vary slowly.

The objective of the problem is to obtain estimates for the solar ultraviolet flux into the ionosphere and the heat conducted to the F region from the protonosphere, by matching theoretically computer temperature curves with these quantities as variable parameters to the experimental curves. As a means of accomplishing the objectives stated above, it is proposed to modify a computer program written by J. E. Geisler for calculating particle temperatures in the ionosphere. The modifications will include: (a) Introducing a substantial heat flux from the protonosphere; (b) Changing the model atmospheres to match more closely the conditions prevailing during sunspot minimum, when the experimental results were obtained; (c) Changing the electron density profiles to match that observed. (George P. Mantas)

2598-75019 T Electrical Engineering. Extraction of Instantaneous Fundamental Frequency From a Harmonic Audio Signal by Digital Computer. A program for extraction of the instantaneous fundamental frequency from a sampled, harmonic audio signal has been developed. A functional using the one-norm is computed for different frequencies in a certain range. The minimum of the functional occurs when the frequency selected is the fundamental frequency. This program, in a simple form, has been tested on the computer. A more general implementation will be tested. (Karl King)

2599-75020 Nuclear Engineering. Concrete Buildup Factors. By use of a previously developed program, FETMOC ("Full Exponential Transformation in Monte Carlo"), suitably adapted, it is proposed to calculate point source gamma ray buildup factors for concrete. Previously published data on this are known to be somewhat incorrect and inconsistent. The computational technique involves primarily the use of stochastic methods for following the histories of photons emitted from a point source of monoenergetic radiation. The resulting radiation field in the assumed material is taken as the average results from all histories. Also, standard deviations are computed by appropriate use of the individual history data. The exponential transformation technique is used to modify the basic Boltzmann equation which is the basic description of the transport phenomenon. The results of this computational program will become the basis for improved data in radiation shielding handbooks, and in particular will be the basis for a contributed article to the nuclear engineering literature. (A. B. Chilton)

2600-75021 T Chemistry and Chemical Engineering. Non-Steady State NMR Spectra. The effect of chemical exchange on non-steady state high resolution nuclear magnetic resonance spectra will be investigated theoretically. The spectra will be calculated from the solution of a set of differential equations of the form:

$$\frac{d\rho}{dt} = A\rho + f$$

where A is a matrix of constant coefficients and f is a time dependent vector. The calculated spectra will be used to show how the chemical exchange rate can be related to the spectral parameters. (E. S. Gore)

2601-75022 T Computer Science. Analysis of Unijunction Transistor Characteristics. In this project, data are obtained from measurement of both the unijunction transistor volt-ampere characteristics and the operation of the unijunction transistor in an oscillator circuit. The computer is then used to correlate and check these experimentally obtained curves with those predicted by theory. Curve fitting techniques - such as a least squares curve fit - will be the mathematical methods most extensively used to do this. The computer will also be used to aid the analysis of the unijunction transistor circuit. This takes the form of numerically analyzing differential equations by Runge-Kutta methods. (Tom Bezdek)

2602-75023 Home Economics. Body Type and Behavioral Dispositions. Sheldon, Sulivan, and others have demonstrated a contingency between body type and personality. Gleuck and Gleuck in a multi-discipline study of factors related to juvenile delinquency isolated body type as a primary factor in predicting such dependent variables as age of arrest, type of conviction, and frequency of conviction. Thus, measures of body type appear to be useful indices of certain behavioral dispositions in the adolescent. However, the relation of body type to personality in the young child has not been extensively studied. In the present study, physiological measures of body type of 32 children (18 males and 18 females), 3 through 5 years of age, will be correlated with behavior in the following categories: achievement, avoidance-withdrawal, friendship-affiliation, dependency, aggression, nurturance, and control-dominance. Correlations between the dependent and independent variables will be partitioned by age, sex, socioeconomic status, and other relevant variables. The analyses will be primarily descriptive since this study is conceived as exploratory. (VandenDaelen)

2603-75024 Chemistry and Chemical Engineering. Calculation of Asymmetric Rotor Spectra. Calculations are made of electronic spectra to be expected for various polyatomic molecules. Both classical and quantum mechanical calculations are performed. The classical calcuations consist of integrating a rotational correlation function by the method of Haselgrove. The quantum calculations are made by diagonalizing the Hamiltonian matrix for both electronic states, calculating the resulting frequencies and intensities of each line, and then blending the lines to form a spectrum. The classical calculations, since they

are approximate but much faster, are used to conduct a rough search for the correct rotational constants, and when suitable approximations are found more accurate values are found by use of the quantum calculations. (Lombardi)

2604-75025 T Marketing. Automobile Buyer Study. The purpose of the problem is to test whether there are significant socio-economic and shopping behavior differences between new-car buyers who are loyal to a given brand and those who switched to a different brand (make) of car. Data on 680 new Pontiac owners were obtained from invoices and from mail questionnaires. Answers were received from 398 subjects, 348 by mail and 50 by telephone follow-up. Of the 398, 138 are brand-loyal, 168 are non-loyal, and 92 had no trade-in when they bought their new car. The principal analytical tool to be used is Multiple Discriminant Analysis (SSUPAC). The objective is to determine which, if any, of the independent variables--e.g., age, income, occupation--discriminate between loyal and non-loyal buyers. (Although tabulations are desired on the no-trade-in group, it is not necessary to derive a discriminant function for them.) Additionally, several cross-tabulations will be done as well as a chi-square analysis. (Robert Gieselman)

2605-75026 T Aeronautical and Astronautical Engineering. Panel Vibrations Induced by Supersonic Boundary Layer Turbulence. The spectral and cross-spectral densities for the random vibration of flight-vehicle panels under the excitation of a supersonic turbulent boundary layer are computed. A normal mode approach is used. The input statistical data for the boundary layer are taken from experimental results which were reported in the literature. (Robert Hellweg, Jr.)

2606-75027 T Education. The Task of the Demonstration Director. The problem is to define the task of the demonstration director in education. Several directors in Illinois were interviewed as the basis of two instruments describing the tasks they performed. One instrument consists of 38 tasks, each task rated in terms of importance on a five-point Likert scale. The other instrument consists of a rank-ordering of the eight major task areas of the director's job. These instruments plus demographic items were administered to all current and former directors in Illinois, a sample of 58. The first

instrument is to be factor analyzed and scores assigned on the basis of the main factors. The directors are then to be compared across 15 variables by a product-moment correlation on both the first and second instruments. The purpose will be to see how these variables affect the director's job. (Ernest R. House)

2607-75028 Electrical Engineering. Application of Fourier Transforms to the Problem of Pattern Recognition. The purpose of this problem is to consider some aspects of antenna aperture synthesis, image synthesis, and holography. The study will also find application in the area of pattern recognition. The investigation is to be based on the Fourier transformation technique using the fact that the field distribution in the object plane is related to the field distribution in the image plane by the Fourier transform relationship. Assuming the information in the image plane is known, this property will be used to synthesize the distribution in the object plane and recognize the object or the field pattern which generates the distribution in the secondary plane. To improve the resolution of the recognition procedure, a suitable analytic continuation method will be tested for the specific problem on hand. Numerical aspects of the problem include evaluation of forward and inverse Fourier transform integrals. (James Richardson)

2608-75029 Education. State School Study. This study involves systems analysis of educational costs, programs, and selected inputs. The purpose is to analyze the "mix" of programs and deployment of staff and facilities, and to pro-rate costs in relation to programs, This is an initial attempt to analyze educational costs on a more functional program basis than traditional accounting structures permit. Comparable analyses are made on a representative sample of school systems in four states--Illinois, Florida, Utah, and Idaho. A test of differences in extent of specialization of staff and differentiation of programs and resources will be made with respect to level of expenditure, regional influences, and other factors. (McLure)

2609-75030 Illinois State University, Educational Administration. Teacher Effectiveness - A Study of Environment and Personality Factors. The problem as proposed for this study is one of investigating the dimensions of interaction between the personalities of teachers and their school work environment. The primary purpose of this study is to ascertain the extent to which a multi-variate analysis of indices of the degree of congruence between personality and environmental variables will discriminate between groups of teachers classified according to effective and non-effective patterns of teaching behavior. Additional purposes of the study are: (1) to compare the relative efficacy of discriminations provided by indices of personality-environment interaction, personality indices, and environmental indices; (2) to compare the relative efficacy of discriminations resultant from multi-variate and univariate analyses; and (3) to evaluate the potential values of indices of personality-environment interaction as predictors of patterns of teacher behavior. The Multiple Discriminant Function technique will be used to test the data. The data were obtained by questionnaire. (Donald J. D'Amico)

2610-75031 Social Work. Clinical Social Attitudes. Two scales of attitudes toward their profession, by social workers, have been established by factor analysis. Scale scores and other data, for a national sample of 817, and about 1000 students in four graduate schools, will be read on to tape to facilitate further investigation of correlates of the attitudes and change in attitudes. For several hundred graduate students, scores are available at two points in time. (Taber)

2611-75032 T Civil Engineering. Idealization of Structures for Seismic Analysis. It is generally realized that a real three-dimensional structure, such as those encountered in modern industrial plants, must be idealized by a simple dynamical system for the purpose of seismic analysis. The uncertainty of the earthquake excitation makes it necessary to consider only gross responses in the routine of design. However, for the more complex structures no comparisons are available of the gross responses obtained by both simple and refined models for the same structure. Therefore, it is proposed to consider structures of somewhat general topology, to idealize them by more refined models using finite elements and matrix techniques, and to compare the gross

responses to those obtained by using simple models. Some consideration may also be given to the behavior of three-dimensional structures subject to earthquake type disturbances. (John C. Galloway)

2612-75033 T Speech and Theatre. Use of Evaluative-Dynamic Language. This study concerns the use of and effectiveness of evaluative-dynamic language in regard to dogmatism, and other directedness of language users and initial attitudes of listeners. Two 2-2-2-2 analyses of variance are the primary methods for analysis of the data for the two parts to the study. Subject tasks are to make choices betwen dynamic versus nondynamic evaluative language and to respond to speeches in which such language is used. Results are expected to support hypotheses that use of dynamic language is related to subject personality variables and to the type of audience that the speaker is addressing and that dynamic language is effective with partisans but is ineffective with a hostile audience. (Helen H. Franzwa)

2613-75034 T Theoretical and Applied Mechanics. Analytical Study of the Flow Around the Bodies. The flows around the flat plate, circular cylinder, and elliptic cylinder are investigated via asymptotic techniques. The Navier-Stokes equation and the continuity equation are used as governing equations. The flow variables are expanded asymptotically in the neighborhood of infinity and near the body, and matched at certain intermediate points to obtain the solution which is valid uniformly in entire space. The drag force and stream functions are obtained numerically on the computer. (Thomas Kim)

2614-75035 T Zoology. Analysis of Parental Behavior of Cichlasoma nigrofasciatum. An appropriate measure of parental behavior in Cichlasoma nigrofasciatum (Pisces: Cichlidae) is parental fanning. While it is fanning, the parental fish circulates water over its brood by means of rhythmic movements of its pectoral fins. That circulation presumably facilitates gaseous exchange. A model describing the structure of fanning has been developed. Based on that model, an appropriate statistic to measure fanning performance appears to be seconds fanning per unit time. The problem to be dealt with here concerns the possible roles of chemical and visual cues that the parent receives from its young in the regulation of the parent's fanning behavior. A system has been developed that permits the observer to selectively vary the parental fish's exposure to these stimuli.

Analysis of variance will be used to determine whether or not removal of chemical stimuli, visual stimuli, or both has a significant effect on fanning output as it is recorded with an Esterline-Angus multi-channel event recorder. (John C. Mertz)

2615-75036 T Education. Study of Practical Nursing Students' Perceptions. The perceptions by practical nursing students of selected health occupation images and the longitudinal and transverse relationships of these perceptions to experiential, demographical, and educational characteristics of these students will be studied. An instrument that utilizes the semantic differential technique of perceptual assessment will be administered to students and instructors at a selected sample of practical nursing programs in Illinois. Supporting data that were previously collected on these same subjects by the Integraged, Longitudinal Study of Practical Nursing project staff will also be utilized. Data analysis will be primarily accomplished through the use of SSUPAC. (Suzuki)

2616-75037 T Nuclear Engineering. Reactor Neutron Pulse Propagation. The research deals with the propagation of reactor neutron pulses through an enriched uranium subcritical assembly. The computer is used to solve an integro-differential equation describing the phenomena. It is further used to analyze data to get the reactor parameters. The standard difference equation technique is used to solve the problem. (P. K. Doshi)

2617-75038 T Education. Decision Making in Educational Program. This is a descriptive survey, first, of the perceptions of educators as to the levels at which decisions about educational programs are made and influenced in elementary and secondary schools. Secondly, it is a survey of perceptions of the same educators as to the levels at which decisions about educational programs should be made and should be influenced, and to compare these perceptions with the perceptions as to the levels at which decisions are actually made.

The data were obtained from a sample of fifty schools in the province of Saskatchewan, Canada, and include as respondents teachers, principals, supervisors, superintendents, and school board members. In addition the perceptions of the staff of the department of education, the college of education,

and members of provincial committees of the Saskatchewan Teachers' Federation were included.

The data were collected through the administration of the Decision Level Analysis Questionnaire and will be analyzed through the use of frequency tables and simple comparisons.

The results will be used to determine patterns of perceptions from various educational roles in Saskatchewan and to establish areas and levels of educational programs in which there is agreement and conflict among educators about the nature of decision making in educational programs. (A. G. McBeath)

2618-75039 T Education. Evaluating Short-Term Teacher Updating Programs in Vocational-Technical Education. The major purpose of this study is an attempt to initiate a model for the development of an instrument(s) to evaluate short-term vocational-technical teacher updating programs immediately upon their completion. McNemar's test for the significance of changes will be used for analysis of the data. This test is particularly applicable to those "before and after" designs in which each person is used as his own control and in which measurement is in the strength of either a nominal or ordinal scale. In addition, mean, median, and frequency distributions for each response to each statement in the instruments will be tabulated. (Menno DiLiberto)

2619-75040 Institute of Labor and Industrial Relations. Analysis of Labor Turnover. The parameters of several models of postulated cross-sectional and time-series relationships between quit-rates, layoff rates, and other labor turnover and economic variables are to be established by standard regression and analysis of covariance techniques. Labor turnover data are obtained from published government field surveys of business firms. (Vladimir Stoikov)

2620-75041 City Planning. Metropolitan Models Sequence. The purpose of this project is to "computerize" an illustrative analytical system for comprehensive metropolitan plan-making. The system in question is being developed to illustrate the role of mathematical techniques and automatic data processing in urban planning practice. It will be produced as a training manual for classroom use in UP 376 (Planning Analysis) and in

continuing professional education courses. When completed, it will comprise an integrated sequence of planning agency tasks, a set of computer programs for performing these tasks, and a small pool of input data which represent conditions in a hypothetical medium-sized metropolitan region. The tasks will provide examples of such basic analytical procedures as estimation, prediction, prescription, and calibration. They will entail a variety of mathematical models ranging in complexity from simple empirical presumptions to input-output, linear programming, and regression-based relationships. The 7094 will be utilized to: (1) Formulate and "debug" a computational sequence embracing a number of simple FORTRAN II programs, together with PORTHOS and SSUPAC library routines for the solution of simultaneous equations, linear programming, and regression problems, respectively; (2) Conduct a complete run of the computational sequence with hypothetical data. (Willard B. Hansen)

2621-75042 T Economics. Empirical Verification of the Market-Segmentation Hypothesis. In this problem an attempt is made to find empirical evidence in support of the Market Segmentation Hypothesis of the term structure of interest rates. Two tests are to be made. The first is to prove that interest rates are not satisfactory independent variables in the various institutional demand for government securities functions. Establishment of this would be consistent with the Market Segmentation Hypothesis and inconsistent with the several competing hypotheses. The other test is to relate changes in the market shares of various institutional buyers of government securities to changes in the term structure of interest rates. Establishment of this would be evidence supporting the Market Segmentation Hypothesis. Single and multiple correlation and regression programs will be involved in both tests. The data were obtained from the Monthly Bulletin, published by the U. S. Treasury Department, and the Federal Reserve Bulletin, published by the Board of Governors of the Federal Reserve System. (John Naylor)

2622-75043 T Accountancy. An Analysis of Market Behavior of Daily Newspapers. The purpose of this research is to explain which, if any, of five oligopoly models best explains the market behavior of firms in the daily newspaper industry. Information to be used in the testing of models will come from interviews, a mail questionnaire, and previously gathered price and output data.

The computer will be used in three aspects of statistical analysis. These include: (1) Several multiple regressions to determine which factors seem to best explain the differences in retail and national advertising line rates to 372 newspapers. The national and retail advertising rates were taken from Newspaper Rate Differentials with circulation, trading zone population, and per capita income taken from Standard Rate and Data Service. (2) Measures of comparative price elasticities of demand for retail and national advertising for a sample of about 80 newspapers grouped by circulation size and by type of competition faced. The linage figures for national and retail advertising were taken from Editor and Publisher magazine. Information about national and retail advertising rates was obtained from Newspaper Rate Differentials, Standard Rate and Data Service, and from the mail questionnaire. (3) Statistical analysis of the questionnaire, with tests to include the following: chi square, analysis of variance, and "t" tests. (Richard D. Brown)

2623-75044 T Civil Engineering. Effect of Curb Parking Maneuvers on Traffic Flow. The purpose of this study is to determine the frictional effects of curb parking maneuvers on traffic flow at midblock locations on urban arterial streets. The computer will be employed to simulate the traffic flow under varied combinations of traffic volumes, street layouts, curb parking geometries, and parking turnover rates. Suitably modified simulation programs which are currently available or a completely new computer program will be used for the simulation. F om the simulation output of volumes, average speed, average delay, etc., the computer will then calculate the natural resources consumed (fixed and variable) as the measure of effectiveness of each situation tested. By assigning monetary values to these resource quantities, it will be possible to determine the economic desirability of providing curb parking on arterial streets and to determine the optimal geometry and turnover rate for streets where curb parking is permitted. (Lee A. Webster)

2624-75045 T Civil Engineering. Effect of Variations on Layered Systems. The layered structural system will be represented by a finite element, lumped parameter model. The variations of material properties will be represented by randomly assigning these properties, in accordance with the probability laws associated with them, to the finite elements of the model. Gauss elimination will probably be used to solve the resulting system of equations for stresses

and strains at the modes. A Monte Carlo procedure will be used to determine the nature of the variability of the stresses and strains in the system. This project will be mainly concerned with developing the method for solving the problem. (James R. Levey)

2625-75046 T Psychology. Analysis of Auditory Detection Response Sequences. Auditory detection experiments were run with human observers who made repeated decisions about the presence or absence of weak sinusoidal tone pulses in a Gaussian noise background. The major concern of the experiments was to discover how observers use information about probabilities of the tone stimuli, and to evaluate several theories that describe how this information might be combined with auditory observations to produce detection decisions. Parameter estimation for these theories requires sequential data for each observer over a large number of stable-performance trials. The computer program provides these data. (Willard Larkin)

2626-75047 T Electrical Engineering. Computation and Interpretation of Holograms. The problem is to simulate on the computer the production and interpretation of holograms. The first aspect of this problem will be to compute the hologram produced by a given object. The second, or inverse problem, will be to evaluate the form of the object or to estimate the currents flowing over it, from the knowledge of a hologram. Eventually, this will be applied to microwave holography where the hologram will be recorded in the laboratory and interpreted on the computer to obtain information about a scattering object or antenna.

The mathematical method will feature a new algorithm for taking the Fourier Transform. This algorithm can reduce the number of complex operations (one complex operation ≡ an addition and a multiplication) needed to Fourier transform a vector X_k ($k = 0, 1, \ldots, N - 1$) from N^2 to $N \log_2 N$. It is anticipated that the problem will involve such special functions as the Gaussian, Bessel, and Prolate Spheroidal Wave functions. (P. L. Ransom)

2627-75048 T Advertising. An Analysis of Consumer Attitudes Toward Retailing Institutions in Central Illinois. There is great difficulty in securing a reliable attitude measurement of the public. This research is an attempt using a pre-tested questionnaire to ascertain opinions and attitudes of consumers concerning a retail institution operating in central Illinois. Techniques used in the questionnaire are semantic differentials, rating scales, and multiple choice responses. Statistical analysis of the data involves one way frequency charts and cross tabulation among certain of the variables. The computer results will give quantitative character to consumer attitudes toward retailing institutions. (Ernest Anderson)

2628-75049 T Civil Engineering. Potential and Elasticity Analysis by Integral Equations. This research is concerned with the solution of the static plate and shell problems of elasticity by integral equation methods analogous to the methods for the boundary value problems of potential theory. Particular singular solutions of the governing equation are used to find boundary functions which will solve the plate or shell boundary value problems. Certain numerical schemes are used to reduce the resulting integral equations to systems of linear algebraic equations which can then be solved by matrix inversion or successive approximation. (Delroy Forbes)

2629-75050 Psychology. Effects of Role Assignments. One hundred and twenty-eight subjects were assigned the task of preparing and delivering a speech which either favored or disfavored the continuation of draft deferments for college students. In a fixed-effects analysis of variance design half were induced to defend the pro and half the con side of the issue; half received adverse and half received favorable feedback from an accomplice to whom they delivered their speech; half believed the accomplice knew that they had been explicitly assigned responsibility for advocating a specific side of the issue and half did not; half delivered their speeches to one accomplice and half to a different accomplice; half were run by a male experimenter and half by a female experimenter. Dependent variables include a variety of measures of the length and persuasiveness of the speech, the subject's perception of the effectiveness of his performance and of the accomplice's appraisals of him, and the extent to which the subject's initial attitude toward the issue of draft deferments is altered in the direction of the position he has been induced to advocate. (Ivan D. Steiner)

2630-75051 Communications. Research Methods in Communications. This project involves a communications research problem conducted by members of the Journ 490B and Comm 492 classes. In a series of separate although related studies, the project is designed to determine the important parameters of effective communication. The particular parameters investigated are as follows: (a) the determinants of pictorial communication, including design layout, the use of color vs. black and white, and the ratio of text to picture; (b) the determinants of effective verbal communication, including speaker acceptance, listener involvement, personological characteristics of listener, and speech content. Here, effective verbal communication is operationally defined in terms of attitude change. These studies will include the use of standard SSUPAC programs such as correlation, analysis of variance, T-test, Chi-square, factor analysis and the rotation of these factors. (Wiggins)

2631-75052 T Psychology. Dimensional Analysis of Binary Data. This research has two phases: the comparison of different multidimensional methods for analyzing items and the investigation of the nature of the Minnesota Multiphasic Personality Inventory. Three methods of analysis will be compared: principal components analysis, Lingoes' multidimensional scalogram analysis, and Tucker's dimensional analysis of binary data. These methods will be compared on hypothetical data matrices and on a subset of Minnesota Multiphasic Personality Inventory items. They will be compared with respect to obtained dimensionality and structure. The inventory data were collected at Stanford on 250 male and 250 female students in introductory psychology. The subset of 100 items will be chosen from the standard clinical scales so as to satisfy certain item characteristic criteria. The dimensions obtained from the analyses will be compared to previous literature on this inventory as well as item and scale characteristics. (A. Conger)

2632-75053 T Communications. Experimental Study of the Listener Engaged in the Communicative Act. An experimental study of the listener engaged in the communicative act was conducted by exposing approximately 300 undergraduates to different combinations of speeches and speakers. The subjects were given two personality tests and an attitude test before the treatment. Various analyses will be run on the data to confirm hypothesized relationships among

the variables: cognitive style, affiliative need, involvement, speaker attraction, and attitude change. Tests will include, but not necessarily be limited to, analysis of variance, uncertainty analysis, factor analysis, and multiple correlation analysis. (Robert B. Fulton)

2633-75054 T Psychology. Three-Mode Factorial Investigation of the Semantic Differential. The project will concern itself with a reanalysis of Semantic Differential data. Semantic Differential data are collected by having subjects rate stimulus objects or words representing stimulus objects on bipolar adjective scales. The reanalysis will be done utilizing the Three-Mode Factor Analysis model. The results from the initial factorings will be rotated to an approximate simple structure. (Snyder)

2634-75055 Advertising. Negro-White Response to "Integrated" Advertising Stimuli. Data were obtained from a sample of 246 middle-income Negro and White residents of Chicago, Illinois. Subjects were selected according to probability methods, using the Chicago "Master Sample" which is maintained by the sampling section of the Survey Research Laboratory of the University of Illinois. Field work was accomplished by the field interviewers of the Survey Research Laboratory. Respondents provided information relative to various demographic characteristics: namely, race, sex, age, education, marital status, number of adults in household, occupation, and income. Respondents judged magazine advertisements by responding to a ten-scale semantic differential instrument. The advertisements varied in terms of the racial composition of the models (only white models, only Negro models, and Negro and white models combined) and the degree of social intimacy of the posed illustrations (socially intimate scenes and non-socially intimate scenes). Analytical methods to be employed are: frequencies and central tendencies according to the various demographic characteristics, factor analyses of the scale and concept matrices, and analyses of variance for repeated measures designs (BALANOVA 5). Results will be analyzed and interpreted in terms of subject differences and/or similarities to the types of advertising stimuli. (Arnold M. Barban)

2635-75058 Chemistry and Chemical Engineering. Crystal Structure Analysis. The research involves the determination of molecular structure in the crystalline state by means of x-ray structure analysis. Computer facilities are necessary in processing the diffraction data, in computing three-dimensional Fourier series, and in getting the best fits of calculated to observed structure amplitudes by the methods of least squares analysis. (I. C. Paul)

2636-75059 T Education. Teachers' Perception of Culturally Disadvantaged Children. The major hypothesis of this study is that teachers will change their perception of students after they have received relevant information concerning: (1) The students' socioeconomic status; (2) How the students' perceive the teacher; (3) Some aspects of the students' personal behavior. The students in this study are defined as those students who attend schools which have at least 20% of their membership having families with $2,000 or less annual income. The design to test this hypothesis is a before-information-after with a control group. A t-test will be used to test for significance. Another hypothesis is that the higher the score on the instruments in the test, the less the change. A correlation coefficient will be used to test this hypothesis. Teachers with 5-9 years experience are expected to change the most and to have a greater decrease in the number of discipline cases which they send to the office than teachers with less than 5 years experience and less than those teachers with 10 or more years of experience. A one-way Analysis of Variance will be used to test for significance for this hypothesis. The data will be collected from teachers and students by the use of questionnaires. (Marvin Willerman)

2637-75060 T Theoretical and Applied Mechanics. Numerical Integration of the Incremental Strain Theory. The Prandtl-Reuss incremental stress strain equations in the theory of plasticity are to be used along with the elastic compressibility relation and the stress strain loading function to predict the stresses in thin-walled steel cylinders loaded axially and internally into the plastic region. These functions are dependent on the strain path followed and thus require a numerical integration of the loading function. An increment of strain is to be chosen and the average stress existing during the application of the small increment of strain is to be found by iteration of the loading function. Three types of cylinders are to be used and each type

is to be subjected to three different loading paths. The loading function (material stress strain curve) for each material is to be determined by tension, compression, and hollow torsion tests. (John L. Schlafer)

2638-76001 Social Work. An Analysis of School Social Work. This study is intended to evolve a definition of school social work which will identify the essential elements in this particular field of social work practice. Answers to these questions are sought: (1) What are the tasks which social workers agree are an important part of the function of school social work? (2) What is the relative importance assigned to these various tasks by a panel of social workers engaged in the practice of school social work? (3) With what groups of children and with what kinds of problems are school social workers most usually involved? (4) Do school social workers reflect different values about the nature of school social work practice? Are there major dimensions of opinion which can be identified? (5) What is the nature and extent of such differences in value patterns as may emerge from a study of school social work? (6) Are there tasks within school social work, and if so which ones are they, for which a rationale exists suggesting that these tasks may be appropriate for performance by manpower with less or different training than that contained in a graduate degree in social work education? A rating scale was used to obtain data from a random sample of school social workers over the United States. They indicated their opinions on the scale as to (a) the relative importance of each of the identified tasks for the attainment of social work goals within a school system, and (b) whether each task can appropriately be assigned to persons with less education and professional preparation than a graduate degree in social work education. A standard factor analysis of the data is the principle statistical method being used. (Lela B. Costin)

2639-76002 Zoology. Bioenergetics of Animals. Physiological measurements are being obtained of the energy requirements of animals for existence at various temperatures and photoperiods and for carrying on various activities, such as reproduction, molt, and migration. Comparisons are being made between animals maintained under constant controlled conditions and caged animals out-of-doors throughout the year. The most important physiological variables

involved are calories per animal per day, weight, body water content, body lipids, body proteins, and activity. The computer will be used primarily to obtain equations for linear and other regressions, and for analysis of variance. (S. C. Kendeigh)

2640-76003 T Chemistry and Chemical Engineering. Determination of Nuclear Magnetic Resonance Lineshapes. Using the criterion of least squares, the computer will be used to find the best fit of experimental data, consisting of high resolution nuclear magnetic resonance lineshapes, to theoretical lineshapes calculated by the Anderson-Weiss theory. (E. S. Gore)

2641-76004 T Advertising. Application of Riesman's Theory of Inner- and Other-Directedness to Magazine Exposure. The purpose of this research is to determine whether people accumulate in magazine audiences along the dimension of social character, as delineated by David Riesman in his book, The Lonely Crowd. The sample will consist of approximately two hundred undergraduate students at the University of Illinois. Two questionnaires will be given to each subject. The first questionnaire determines the student's exposure and general feeling towards each of twenty magazines listed. The second questionnaire, called the "Inner-Other Directed Social Preference Scale," was developed by Waltraud Kassarji and consists of 36 items based on Riesman's descriptions of inner- and other-directedness. Each item may be answered along a five-point scale--the "I-O Scale" (inner-other). The scale is used to determine the spread of scores along a continuum from inner-directedness to other-directedness. For statistical analysis the subjects will be divided into quartiles based on their scores on the "I-O Scale." A correlational analysis will be run to see if segments on the inner- to other-directed scale correlate with certain types of magazines and catagories of magazines. (Jerry J. Belson)

2642-76005 Civil Engineering. Stability of a Slope During Earthquake. The computer program is aimed at evaluating the minimum value of acceleration force that a slope with a given profile and soil properties can survive, when the ground is shaken by an earthquake. Even though the slope is stable in the static condition, the stability will be lost as the acceleration of an earthquake shaking increases. The acceleration that makes the factor of safety down equal to one may be considered as that which makes the slope about to slide. In order

to determine the acceleration, a large amount of repetitive computation must be made, assuming a number of trial sliding surfaces in succession, until the minimum factor of safety is found. This procedure requires the location of a trial sliding surface in terms of a rectangular coordinate system, and then computation of a resisting stress that is mobilized along the assumed sliding surface. The factor of safety that is defined as a ratio between an available strength of soil and the mobilized working stress does not generally give the minimum value for an arbitrary chosen sliding surface, and therefore this procedure should be repeated a number of times, until the sliding surface is found that gives the minimum for the factor of safety. The factor of safety thus determined will be useful to judge if a given slope is safe or not against an expected earthquake. (Kenji Ishihara)

2643-76006 T Civil Engineering. Stress Analysis of Shell Structures. The object of this study is to develop a computer program for the numerical stress analysis of shallow shell structures. The method used is the so-called "finite element" technique, which has the effect of replacing the governing partial differential field equations with a set of simultaneous linear algebraic equations. The computer is used to automatically generate the set of simultaneous equations, which are then solved, for the unknown nodal generalized displacements, by the Choleski (or Square Root) Method. Once the nodal displacements are known, a simple process of back substitution yields the internal stress resultants. The results of the analysis, i.e., displacements and stress resultants, can then be used to check the adequacy of the shell structure under consideration. (D. Pecknold)

2644-76007 Psychology. Voting Behavior. In the past, voting behavior has frequently been thought of in terms of group demographic variables. This view of political man has proved to be rather unsatisfactory in explaining voting behavior. The more recent trend has been to look to more personal variables as an alternative. This study falls within this newer trend in analyzing beliefs and evaluations held by the potential voter as an explanation for subsequent voting behavior. Interview data have been gathered locally during studies of the election campaigns of 1962, 1964, and 1966, on three levels: congressional, senatorial, and presidential. These interviews were a

random sample of the local populace, whose subsequent voting behavior closely parallelled that of the Champaign-Urbana populace as a whole. The findings of these three studies will be analyzed primarily by means of factor analysis, analysis of variance, and correlational programs. The computer results will be used as an aid in integrating the findings of the three studies mentioned above. (Martin Fishbein)

2645-76008 Agronomy. Chemical Changes in Soils. The objectives of this study were to investigate the extraction characteristics of the aluminum-bound fraction of phosphorus in different soils. Experiments were designed to study the rate of extraction of phosphorus from soils along with factors affecting the extraction. Soil constituents which are active in the conversion of added fertilizer to the aluminum bound fraction have also been studied by measuring fluoride-extractable aluminum in soils.

With the use of correlation and regression analyses, the relationship between phosphorus and aluminum can be found. In addition, analysis of variance will be used to study the effect of several variables such as extraction time, solution ratio, reagent concentration, and reagent pH on the amount of phosphorus extracted. The presence or absence of interactions between different factors studied will further aid the standardization of methods of phosphorus extraction.

The aluminum-bound phosphorus has been shown to be an important fraction in supplying phosphorus to plants and a detailed study of this fraction can lead to a better planning of soil-plant-fertilizer programs and evaluation of phosphorus fertility of the soil. (Kurtz)

2646-76009 Agricultural Economics. Intertemporal Analysis of Illinois Agricultural Commodity Markets. The purpose of the research problem is to formulate dynamic economic models which reflect the production processes, the structure of the markets and the mechanism by which the prices of principal Illinois agricultural commodities are generated. In addition, it may be necessary to develop and refine statistical and other methods of analysis that will permit one to assess quantitatively these formulated models.

Quantification of the models would involve the use of multiple regression techniques for production response analysis; simultaneous equation models to estimate price-demand structures; linear programming or quadratic programming techniques for decision models; Bayesian techniques to take account of the latest information in forecasts; and simulation techniques to evaluate alternative policies. The estimated relationships will be used as a basis for the construction of optimal decision rules with the aim of market expansion, revenue maximization, prediction and evaluation of alternative policy choices. (R. J. Vandenborre)

2647-76011 Materials Research Laboratory. Infrared Optical Properties of Impure Solid Rare Gases. The infrared absorption and first order Raman scattering induced by a low concentration of defects in a monatomic face-centered cubic lattice will be calculated using Green's function techniques. It is planned to determine the localized mode frequencies, the band mode absorption, and the band mode scattering. The computer will be used primarily for matrix multiplications and inversions. (T. Patrick Martin)

2648-76012 T Physiology. Ion Fluxes in Muscle. The ionic events occurring at the membrane of nerve and muscle during depolarization have been extensively studied but only partially understood. It is widely accepted that there is a flux of Na^+ and K^+ ions through the resting membrane. Depolarization is attributed to the opening of Na^+-specific channels in the membrane, with resulting increased Na^+ influx; repolarization is attributed to the opening of K^+-specific channels and the resulting increased K^+ efflux. This basic model has been challenged by a few workers who claim that the larger Na^+-K^+ fluxes are an artifact of direct stimulation of nerve and muscle and further that the fluxes of indirectly stimulated nerve and muscle are no greater than those for the resting nerve and muscle.

The present study will attempt to measure efflux of K^{42} in resting and directly and indirectly stimulated frog sartorius muscle. The muscle will be treated as a two compartment system where the rate of efflux will be compared for the different parameters. (Frederick Lang)

2649-76013 Recreation. Glencoe Attitude and Interest Study. This research problem is an analysis of Glencoe, Illinois adult and youth leisure attitudes, interests and behavior patterns. Various multi-variate statistical procedures will be used to: (1) Analyze frequency of recreation participation over specific time periods; (2) Analyze relationship of demographic variables to recreation participation patterns; (3) Make exploratory attempts to identify (a) new trends in activity participation, (b) significant demographic or attitude variables that explain activity participation. All data for this research was obtained through questionnaires randomly distributed in the community and in the community's school age population. A 50% youth and 40% adult usable return on the questionnaire was obtained. (Kapplan)

2650-76014 Physics. Hard Core Potential. The ground state energy of a system of two quantum oscillators coupled by a hard core potential is calculated by means of a variational method. Integrals of the form

$$\int_{|x|>a} e^{-x} f(x)\,dx, \qquad \int_{|x|>a} e^{-x^2} f(x)\,dx$$

occurring in this problem have to be evaluated numerically by a computer. (Karl Michel)

2651-76015 State Water Survey. Cloud Droplet Behavior Study. This project is primarily concerned with a theoretical determination of the scattered light by two spherical cloud droplets when they are illuminated by a collimated beam on a point source of light. The purpose of the project is to study the behavior of cloud droplets in very close proximity by studying the scattered light variations. (Daniel Stigliani)

2652-76016 Electrical Engineering. Electron Density in the Ionsphere. The electron number density N(h,t), where h is the altitude and t the time, can be described by the nonlinear parabolic partial differential equation

$$\frac{\partial N}{\partial t} = q(h,t) - L(h,t,N)\ N + A(h,t)\ \frac{\partial^2 N}{\partial h^2} + B(h,t)\ \frac{\partial N}{\partial h} + C(h,t)\ N$$

with the boundary conditions

$$N(h_o,t) = N_o$$

$$D(h,t) \frac{\partial N}{\partial h} + E(h,t)\ N = F(t) \quad \text{at } h = h_L,$$

where $h_o < h_L$. This is equivalent to specifying the value of electron density at the lower boundary, N_o and the flux of electrons F at the upper boundary. An initial condition N(h,o) must also be given. The coefficients A, B, C, D, and E, and the driving force q involve ionospheric parameters for which reasonable values from the literature will be used. The differential equation is approximated by a difference equation involving two time levels (backwards difference method). The nonlinear term is approximated by using the value of electron density at the previous time point in the coefficient L. The resulting algebraic problem is then a system of tridiagonal linear equations. A special version of Gaussian elimination is used to solve this system. The results, i.e., electron number density profiles, will be compared with experimentally obtained profiles, especially incoherent radar scatter and satellite ionosonde profiles. (K. C. Yeh)

2653-76019 T Aeronautical and Astronautical Engineering. Panel-Stringer-Frame Dynamic Analysis. The Panel-Stringer-Frame Dynamic Analysis is here restricted to the steady state response of a single rectangular flat plate supported by open section beams along two adjacent edges and simply supported at the other two edges. The method of analysis is the use of FOURIER Series to represent the various deflection functions. Input data consists of the description of the arbitrary forcing pressure and the physical constants of the built-up structure. The results will be used to check the accuracy of the analysis. (B. K. Donaldson)

2654-76020 City Planning. Factors Causing Land Value. The purpose of this project is to examine the following hypotheses: the price paid per square foot for urban residential land varies inversely with some function of the distance of that land from the center of the city; the price paid per square foot for urban residential land is not influenced by proximity to various public and semi-public facilities such as public buildings, churches, schools, etc.; and the difference between actual price paid and regression price is a function of the relative social attractiveness of a particular location or area. Regression analysis will be used to examine the above hypothesis which will include linear, exponential and power tests. The data were obtained from land sales records of the Illinois State archives. Approximately 4000 observations have been compiled for about 35 cities and towns in Illinois. The time period of this study starts in 1855 and ends in 1900. All data represent the first sale of urban parcels from the public domain to private individuals. The results of the computer will be used to test directly the above stated hypothesis as well as to suggest the formulation (if necessary) of additional approaches to the course of land value variation. (Jerrold Voss)

2655-76022 T Office of Agricultural Communications. Continuing Education Via Mass Media. To evaluate the experiences of continuing education institutions in conducting structured educational efforts by mass media (television, radio, magazines, newspapers and direct mail) for participants not enrolled for academic credit. To determine what the relationship is between institution, subject matter, instructional technique, instructional method and mass media. To assess why some efforts were successful and others were unsuccessful according to the subjective evaluation by the institution conducting the effort. A mail questionnaire has been developed and pretested on an Illinois sample. The final edited version will be sent to the directors of continuing education institutions or their equivalent as identified from the current membership list of the Adult Education Association, to the director of adult education in each state and to the director of each agricultural information staff for each state land grant university. Data will be collected from the respondent regarding subject matter, instructional method, instructional technique and mass media used. A three-dimensional classification

scheme constructed from one proposed by Coolie Verner in Adult Education Theory and Method will be used to speed up the analysis and assessment of the data. The computer results will be used for the construction of tables according to the above classification scheme. (Jack C. Everly)

2656-76023 T Chemistry and Chemical Engineering. Calculation of ESR Hyperfine Coupling Constants. This problem consists of carrying out extended Hückel molecular orbital calculations in order to evaluate electron-spin resonance hyperfine coupling constants. The major mathematical operation to be carried out is the calculation and adjustment of matrix elements, followed by a diagonalization of the matrices. The data will be used to deduce the electron density at various nuclei. This electron density determines the electron-spin resonance spectrum of the molecules under study. (R. Cramer)

2657-76024 Education. Measuring Agricultural and Biological Interest of Eighth Grade Students. The research will be concerned with the Vocational Agriculture Interest Inventory developed in Pennsylvania by Professor Robert W. Walker. The instrument has been validated in Pennsylvania and has proven to be a useful guidance tool for predicting the success of eighth grade students who would pursue courses of study in agriculture and applied biological science. The validity of the Pennsylvania instrument will be determined by administering the interest inventory to selected groups of Illinois eighth grade students and comparing the resulting responses with the responses of Pennsylvania eighth grade students. (Robert W. Walker)

2658-76025 Center for Zoonoses Research. Emergence and Recession of the Zoonoses - Research. The general objectives of the research program are to elucidate various basic factors that may be responsible for the phenomena of emergence and recession of the zoonoses. These diseases involve multiple hosts for each of a number of parasites and are therefore especially subject to modification by environmental and hereditary influences. The approach and attack embrace intensive multidisciplinary team study of the ecology of component hosts and parasites of selected zoonoses. An ancillary objective of the research program is to afford science degree and postdoctoral training for students and professionals in the wide range of disciplines represented by the Center's faculty and consultants. (Robert H. Kokernot)

2659-76026 Education. Teaching Model. This problem entails a Flanders Interaction Analysis as performed on the classroom activities of forty "successful" teachers from secondary public schools in disadvantaged areas of Chicago. The purpose of the analysis is to determine what, if any, patterns of interaction between these teachers and their students can be isolated to determine in part what characterizes effective teaching in this situation. It is possible that these identified approaches can be taught to students preparing to teach in disadvantaged urban areas so that they too may become effective. The data were collected by first recording the teachers in their Chicago classrooms over a period of several months during the fall of 1966, and then analyzing the resulting tapes at a later date on the University campus. The analysis used was that developed by Flanders, consisting of numerical symbols representing the various possible classroom interactions. (Doolittle)

2660-76028 T Psychology. Analysis of Moods. The proposed study is an exploration into the domain of psychological states. The research strategy was to collect detailed information on a small group (20) of subjects over an extended time period. The independent variables were the everyday effects of the environment upon the individual subjects. It was felt that life itself can be depended upon to induce a sufficient amount of diversified situations during the testing period to give a reasonable indication of the psychological states. The dependent variable consisted of both questionnaire and objective test data. The data will be analyzed by the Chain P technique described in Cattell and Scheier's Neuroticism and Anxiety, 1961 pp. 168-9 and in Cattell's Handbook of Multivariate Experimental Psychology, pp. 362-4. Each subject's score on any one response variable will be brought to the same common mean and sigma, thereby eliminating interindividual differences. Then each of the nine measures on each variable for each of the twenty subjects will be strung together into a chain series. Each variable will be correlated with all the other variables and then factor-analyzed. The Chain technique is used since we are looking for what is common to human nature and therefore we are interested only in the state response patterns which are common to all. (J. Curran)

2661-76030 Geography. Vital Statistics Mapping. The research problem is concerned with optimum procedures in age-adjustment of mortality and other vital statistics and the mapping of this information by county or other administrative unit. The data have been drawn from published statistics of the National Center for Health Statistics. The computer will be used to prepare adjusted rates through use of the SSUPAC transformation program. (Armstrong)

2662-76031 Civil Engineering. Monte Carlo Backscattering Calculations. The density of a material can be measured by detecting the intensity of gamma radiation scattered back from that material. Such backscattering gauges are empirically calibrated, but there remains a measure of ignorance as to exactly where the radiation penetrates in the measured material. In this project typical photon paths will be simulated by a standard Monte Carlo calculation, and the output so organized as to allow plotting of these paths. (Preiss)

2663-76032 Civil Engineering. Generalized Gradually-Varied-Flow Profiles. Gradually-varied-flow profiles in a wide open channel will be generalized by using a dimensionless coordinate system and the normal flow Froude number. A characteristic length used to form the dimensionless coordinate system could be the normal depth, transitional depth, and critical depth, depending on the type of problem under study. For instance, the transitional depth that is independent of the discharge may be preferred to the other characteristic lengths in one type of the problem where the roughness and bottom slope are all fixed and the profiles vary in accordance with the discharge or the normal-flow Froude number, whereas in another type of the problem such as a flow on a horizontal slope, the critical depth seems the only characteristic length can be used. The flow profiles will be thus computed by using the gradually-varied-flow equation. The result will be analyzed and presented in such a way that the generalized-profiles chart will facilitate the direct application of the equation without resort to tedious computation. (Cheng-Lung Chen)

2664-76033 Electrical Engineering. Cassegrain Antenna. The project is intended to study the ionosphere, using the Thomsen Scattering technique. To this end, a large radar antenna is needed. The objective of this numerical analysis is to develop a new design for the antenna. Computations will involve the determination of eigenvalues and eigen functions, evaluation of diffraction integrals and various properties of the antenna. (Y. T. Lo)

2665-76034 Physiology. Amino Acid Uptake in Euglena gracilis. The uptake of amino acids by Euglena gracilis will be studied by standard radioisotope tracer methods, using C^{14} and H^{3} labeled compounds. Aliquots of the extracts of the cells will be counted with a liquid scintillation counter. The computer will be used to determine quench correction curves by solving appropriate least squares equations, and it will also be used to calculate inter- and extra-cellular concentrations of the various amino acids, as well as to calculate cell volumes and cell surface areas, based on gravimetric measurements, cell counts, and other similar measurements. The computer output will then aid in characterizing the mechanisms of amino acid up-take in the various strains of Euglena gracilis employed in the study. (Lynn B. Graves, Jr.)

2666-76035 Civil Engineering. Software Development for Engineering Design. The purpose of the project is to investigate the incorporation of comprehensive structural design in the undergraduate Civil Engineering curriculum. The proposed study will include the adaptation of existing computer routines for student use and the development of a course which will use these tools to give students education in the whole structural design process. (L. T. Boyer)

2667-76036 Chemistry and Chemical Engineering. Hyrdogen Molecule Perturbation Theory. It has been shown in previous work that, starting from the bare-nuclei problem as zero-order Hamiltonian, calculation of the first-order wavefunction is sufficient to give the energy of the various excited states of the hydrogen molecule to chemical accuracy. The calculation is performed by the Hylleraas-Bethe-Salpeter variation-perturbation method. It is now interesting to examine several extensions of this work: (1) Can one do equally well using the atomic bare-nucleus problem as zero-order Hamiltonian? This would simplify much of the calculation. (2) Can one

calculate potential energy curves rather than simply energies at one internuclear distance? (3) Can one use these wavefunctions to completely predict the positions and intensities of the lines in the ultra-violet spectrum of the molecule? The techniques to be used are standard matrix manipulation techniques, as well as numerical integration schemes designed for the integrals one is to encounter in this work. (Jerry Goodisman)

2668-76042 T Chemistry and Chemical Engineering. Optical Studies of Dinucleotide Analogs. In order to examine the importance of base-base interactions in maintaining the secondary structure of nucleic acids, a series of dinucleotide analogs, $B(CH_2)_3B'$, where B and B' are 9-substituted adenine or guanine or 1-substituted cytosine, thymine, or uracil, have been synthesized. In these simplified models the polymethylene chain is of sufficient length to allow (but not dictate) vertical ring stacking similar to that found in nucleic acids. These compounds have been studied optically at concentrations low enough to preclude formation of intermolecular complexes.

The decrease in integrated ultraviolet absorption intensity of an analog relative to the sum of the intensities of its component parts $(B(CH_2)_2CH_3 + B'(CH_2)_2CH_3)$ is referred to as hypochromism (H) and gives a semi-quantitative measure of the strength of base-base interactions. Hypochromism is defined as

$$H = (1 - f_{dimer}/f_{monomers})100 \text{ in } \%$$

where f_{dimer} is the oscillator strength of the analog and $f_{monomers}$ is the sum of the oscillator strengths of the corresponding N-propyl bases. The oscillator strength of a given compound is proportional to the integrated area (optical density vs. frequency) of its electronic absorption spectrum. Numerical integrations of absorption spectra will be performed by a computer program based on Simpson's rule. The area so obtained will be employed to calculate the hypochromism characteristic of each analog. (Douglas Browne)

2669-76043 Geology. Exploratory Research in Strata Correlation. Investigation of quantitative methods for correlating rock strata will be made. Various techniques, data smoothing, autocovariance, spectral density, and trend analysis, will be studied. The data are qualitative field descriptions which have been quantified for this work; results are intended to lead to a proposal for a grant for more extensive study of these techniques in stratigraphy. (C. John Mann)

2670-76045 T Theoretical and Applied Mechanics. Effect of Stress Concentration on Natural Frequency of Multi-Stepped Beams. The investigation consists of analyzing the lateral vibration of a simply supported, multi-stepped beam. Present methods of analysis of beam vibrations neglect the effects of stress concentrations. An analytical method is developed for the prediction of the natural frequency of stepped beams which includes the effects of stress concentrations at changes in cross section. Energy methods are used to determine the deflection of the beam and matrix iteration techniques are used to evaluate the natural frequencies of the beam. (H. R. Fjellman)

2671-76046 T Materials Research Laboratory. Cyclically Loaded Tensile Parameters. Cyclic loading of high purity copper single crystals will be used to study the orientation dependence of the tensile properties of copper in the microstrain region. Standard techniques will be used to compute parameters such as the resolved shear stress and strain and the elastic modulus from the raw data for each load-unload cycle. (John Hebeisen)

2672-76047 T Psychology. Multidimensional Scaling of Dimensional Dominance. The Tucker-Messick procedure of Cluster Analysis will be used to scale the dominance of form or color for children in a discrimination learning task. Correlations between the scaled dominance scores and learning speed and accuracy will then be found. Raw data for the dominance scores are obtained by a triadic method in which children are asked to choose from two comparison stimuli the one which most resembles a reference stimulus. Comparative distances among the stimuli are obtained for each child by Torgerson's method, which requires changing raw proportions into corresponding normal deviates.

The matrix with comparative distances as rows and subjects as columns is multiplied by its transpose to obtain a square matrix. The Tucker-Messick procedure provides a means of approximating this matrix by one of lower rank. The number of different clusters of similar viewpoints is indicated by the dimensionality of the approximating matrix. Loadings of individuals on the different viewpoints will be correlated with measures of performance on a discrimination learning task as part of a thesis research project. (Seitz)

2673-76048 T Education. Body Concept and Self Esteem. This project investigates the relationship of body concept and self-esteem in matched paraplegic and non-disabled student groups, and a paraplegic non-student group. Investigative measures included a body semantic differential, an esteem semantic differential, a word association "homonym" test of body concern, as well as figure drawing and self-report techniques. The data will be statistically analyzed primarily utilizing "t" tests, correlation coefficients, and Cattell's coefficient of profile similarity. The research instruments were combined in booklet form, and were presented to both individual or small groups of subjects. The word association test was administered to the student groups by means of a tape recorder, and by means of the telephone to the non-student group. The computer results will be used in a dissertation, as well as any publications which might evolve from this study. (Jack Genskow)

2674-76049 T Psychology. Effects of Experimenter Expectancy in Studies of Verbal Conditioning. The main purpose of this study is to determine whether the incidence of reports of awareness in studies of verbal operant conditioning is affected by the experimenter's "expectation" concerning awareness. In particular, three groups of experimenters were informed either that (1) conditioning occurs without the subject being aware of having been conditioned (low expectancy group), (2) conditioning occurs only for subjects who are aware (high expectancy group), or (3) no information concerning awareness was given (no expectancy group). The incidence of awareness reports and the conditioning performance of subject's seen by experimenters in these expectancy groups are then compared between groups and within (to determine if differences occurred among experimenters within each group). As another factor, the awareness questionnaire was administered

by either a high or low expectancy interviewer. Two different questionnaires were also used. So the basic design refers to a five-way ANOVA with repeated measures; the various factors being, (1) expectancy group (high, low, or no); (2) individual experimenters (nested with #1); (3) awareness questionnaires (form A or B); (4) interviewer groups (high or low); (5) individual interviewers. The main portion of the data will be submitted to the Balanova 5 program in SSUPAC. (Doctor)

2675-76050 T Psychology. Effects of Amygdaloid and Ventromedial Hypothalamic Damage on Regulation. The research project is aimed at assessing effects of amygdaloid complex lesions on food regulatory ability of rats under a standard test situation and in comparison with ventromedial hypothalamic lesioned animals, and nonlesioned animals. Food intake of three differently palatible diets (sugar diluted, quinine contaminated, and plain Purina Laboratory Chow), water intake and body weight were determined both before and one month after surgery. The data are to be analyzed via an unweighted means analysis of variance (factors are lesion site, order of feed presentation, and food). (Ellen F. Rosen)

2676-76051 Botany. Molecular Weight Determinations of Proteins. The molecular weight of a protein may be determined through the proper evaluation of data obtained from an analytical ultracentrifuge sedimentation equilibrium experiment. In such an experiment, a macromolecular substance, dissolved in an appropriate buffer, is sedimented until an equilibrium concentration gradient is established.

The state of sedimentation equilibrium may be taken as the state at which equilibrium is attained between the transport of a solute due to sedimentation and the reverse transport from diffusion.

By employing the Rayleigh (interference) optical system of the analytical ultracentrifuge, concentrations at various points in an analytical cell can be determined with respect to the distance from the center of rotation. The logarithms of the concentrations at various points are then plotted versus the squares of these points. The slope of a line connecting the points generated by such a plot gives the molecular weight of the substance.

A program using a least squares routine from the computer facility library has been constructed to calculate the molecular weight and molecular weight distribution from the Rayleigh optics data. (M. E. Reichmann)

2677-76053 T Agricultural Economics. International Wheat Trade. International wheat trade will be analyzed in two stages: a multiple regression model for the Four Exporting Countries using a step-wise regression model in order to select the most significant variables affecting the dependent variable--the total export of wheat will be developed; and an import-export matrix will be used to analyze the world wheat trade. Each year will be represented by a matrix which is to be transposed, post multiplied and the result will be inverted and multiplied by the matrix for the following year. Out of this matrix presentation the diagonal elements in each matrix will be used to describe the annual changes in wheat trade. It will be clarified more by a diagramatic presentation for these variations. Further non-quantitative presentation for the problem, especially those related to policies followed by different exporting and importing countries will be presented in the context of the analyses. (Alkaddo)

2678-76054 Zoology. Salmon Fishery and Rainfall Correlation. Since the late 1930's it has been known that an apparent correlation exists between salmon catch in the outwash of the Miramichi River, New Brunswick, Canada, and the rainfall during the months of July and August three years earlier. This correlation was discovered initially by visual inspection of rainfall and salmon fishery data plotted as frequency polygons. This correlation, which has been widely quoted in the ecological literature since the 1930's, has never been placed on a more rigorous statistical basis.

Preliminary attempts to do so, using first the Pearsonian product-moment calculations, and second a method of contingency testing involving right- and left-turn ratings assigned to the frequency polygons, both confirmed the statistical validity of the three-year correlation. By both methods, however, equally strong correlations were detected at a displacement of six years and at one of zero years (or year-for-year alignment).

Supported by the Sport Fishing Institute, Washington, D.C., an attempt is being made to develop another approach to serial correlation that will be free of certain problems of non-independence and irregular distribution that may be responsible for spurious correlations by previous methods of

analysis. Each point on the frequency polygon is rated by the difference between its actual height, and the greater or lesser height it would have attained if the trend between the two previous years had remained unchanged. The ratings within the single graph are therefore already linear combinations of variates, which ought to be normally distributed under the central limit theorem. The variances of each graph are calculated and pooled in the standard way; the ratings of the two graphs are then subtracted from each other, and the variance of their differences is then calculated. The ratio of these two variances should be distributed as F with appropriate degrees of freedom, and preliminary tests on a small scale demonstrate satisfactory agreement with the F distribution. The 7094 computer will be used to produce a large-scale Monte Carlo simulation of the test, to determine empirically if indeed a satisfactory F distribution is attained by these procedures. (Arthur W. Ghent)

2679-76055 T Graduate School of Business Administration. Mathematical Programming and Capital Budgeting. This project deals with the utilization of mathematical programming techniques as a device for rationing capital in a decentralized business organization. Extensive use of SSUPAC's linear programming routine is required. The primal formulation of a linear programming model provides a means of selecting that combination of capital projects which maximizes the value of the objective function subject to a set of budget constraints. The value of the variables generated in the dual formulation serve as prices for rationing capital within the context of decentralized decision making. The data that are used are drawn from a hypothetical decentralized business organization. (J. D. Forsyth)

2680-76056 T Computer Science. Sankin's Simulation of ILLIAC IV. The original program for Sankin's simulation of the ILLIAC IV computer is compatible only with the Burroughs B-5500 ALGOL compiler. This program must be revised so as to be compatible with the IBM 7094 ALGOL compiler; then, programs representative of those which will be run on ILLIAC IV will be processed by the simulator, which will calculate the amount of time each system element of ILLIAC IV would have been utilized. From these data, the most efficient size and arrangement of these elements will be determined. The size of such elements and their arrangement within ILLIAC IV can be varied simply by changing parameters in the simulator program. (Warren Sterling)

2681-76057 T Nuclear Engineering. Study of the Internal Conversion Electrons in Fission. This investigation will study the internal conversion electrons emitted from fission fragments in the fission of U-235 and Cf-252. Internal conversion electrons are emitted as the result of the de-excitation of low energy excited levels of the fission fragments. Characteristic x-rays are emitted as the vacancies caused by internal conversion are filled by electrons from higher shells. The energies of these x-rays are characteristic of the charge of the fragment and hence the internal conversion spectra from each atomic charge of the fission fragments can be found. The energies of the electrons and of the x-rays are placed on magnetic tape by a two parameter data acquisition system. The computer is then used to sort the data, and for data analysis such as correction for backscattering and solid angles, and unfolding of spectra. (N. Shapiro)

2682-76059 Computer Science. Analysis of ILLIAC IV Logic Circuits. Mathematical models will be constructed for a number of the ILLIAC IV logic circuits. The analysis of each circuit may include direct current, parameter variation, transient, worst case, and noise margin and reliability investigations. Results of analysis will be used for operational simulation and design optimization.

The primary circuit analysis program to be used initially is an electronic circuit analysis program (ECAP) supplied by IBM. Other routines may be used as they become available such as PREDICT, NET-II, SCEPTRE, CALAHAN, and CIRCUS. Specific mathematical details are not available for any of these network analysis routines at the moment. The mathematical routines used in each of these programs will be investigated with the objective of determining the optimum routine for each ILLIAC IV analysis requirement. (D. Wood)

2683-76060 Economics. Macroeconomic Stabilization Models. The problem consists of evaluating certain stabilization policies for a non-linear stochastic macroeconomic system. An aggregate Cobb-Douglas production function is employed and adjustment toward desired equilibrium positions is governed by the excess demand price for labor and excess capital capacity. A stochastic dynamic programming model is employed to optimize a specified social welfare function over the planning horizon subject to

the above adjustment mechanism. The transformation of four of the state variables is achieved by means of a system of non-linear difference equations whose parameters have been estimated from quarterly data over the period 1960-66 inclusive. The transformation of the fifth state variable is determined by a set of transition probabilities. The program is designed to compute the optimal level and timing of the control or decision variables and to test the sensitivity of the model to various parameter changes. The results from the model may prove useful in suggesting the product mix and optimal schedules for fiscal policy measures. (Franklin R. Shupp)

2684-76061 T Education. Classroom Alienation. This problem deals with the effects of alienation in the classroom. Different levels of alienation were introduced into classroom settings and data collected regarding the attitudes and learning of the students. These data are to be analyzed using factor analysis and analysis of variance techniques. Results will be used in the author's doctoral disseration. (Wm. Mayberry)

2685-76062 Civil Engineering. Pavement Testing. Many moisture content and dry density determinations have been made for three test pavements which have been constructed and tested in the University of Illinois Test Track. The IBM 7094 computer is to be used to make a statistical analysis of these properties. (E. Barenberg)

2686-76064 Physical Education for Women. The relationship Between Body Types and Personality Traits of College Women. The purpose of this study is to determine the relationship between body types and personality traits of college women. Photographs were taken of the college women and were somatotyped by Dr. William Sheldon. Each subject was also given two personality tests: the Sixteen Factor Personality Questionnaire and the California Psychological Inventory. Mathematical methods which will be used include correlations, canonical correlations and multiple discriminate analysis. The results will be used to determine whether there is any relationship between body types and personality factors, and also to determine which personality traits discriminate between body groupings. (Mary Slaughter)

2687-76065 Chemistry and Chemical Engineering. Monte Carlo Calculation of Electronic Correlation. The correlation energy for helium is usally taken to be the difference between the experimental energy and the Hartree-Fock energy. It is proposed that a simple numerical, Monte Carlo type calculation can be used to obtain the correlation energy from Hartree-Fock-like wave-functions:

a. Randomly choose the coordinates of the first first electron weighting the choice of the radial coordinate by the value of the wave function at that value of the coordinate.
b. Randomly choose the coordinates of the second electron--again weighting by the value of the wave function at that value of all three spherical polar coordinates.
c. Calculate the non-correlated potential energy as the simple coulombic repulsion between the electrons.
d. Weight the potential energy by the relative probability of occurrence of the interelectronic distance. This probability is assumed to be a Boltzmann factor involving the ratio of the potential energy to the electronic kinetic energy. This process yields the correlated potential energy.

By finding the average of a large number of individual calculations as outlined above, uncorrelated and correlated values of the average potential energy can be calculated. The difference gives the correlation energy, and the uncorrelated value of the average potential energy can be used as a check of the method and the number of calculations which must be performed.

This method of calculating correlation energy can in principle be extended to many electron atoms and molecules. But the first step, and the scope of the problem here undertaken, is to perform the calculation for the simplest real case--that of helium--to decide whether the method has any validity. (A. Keith Jameson)

2688-76066 T Aeronautical and Astronautical Engineering. Solution of Polynomial with Complex Coefficients. This problem is concerned with the flutter analysis of a semi-infinite viscoelastic panel. This is done by substituting the differential viscoelastic stress-strain relations for a standard linear solid into the equilibrium equation for a panel as derived

from strain-displacement relations. The result is a large order differential equation which is solved by Galerkin's method. The solution thus obtained is simplified to two terms of the infinite series. This then gives two equations in two unknowns. The condition for a non-trivial solution is then applied resulting in an eighth degree polynomial in two unknowns, ω (the flutter frequency) and U (the flutter speed), with complex coefficients. The imaginary and real parts are then separated giving two equations in two unknowns. Here the computer is used in the following way. A U is selected and ω is iterated on to find the solutions to the real and imaginary equations by the binary chop method. A new U is then selected and new ω are computed. A table of the U's and corresponding ω's is then printed out. The researcher than scans down the table to the point where the ω's from the real and imaginary equations are equal. The corresponding U is then the flutter speed and the ω is the flutter frequency. Since the coefficients of the polynomial are also functions of temperature, the variation of U and ω with temperature could easily be obtained by choosing a new temperature and repeating the above solution of the polynomial on the computer. (R. Timpson)

2689-76067 T Advertising. A Procedure for Establishing a Set of Criteria for Selection of Farm Magazines - A Survey Approach. This advertising research problem involves a procedure for establishing a set of criteria for selection of farm media--a survey approach. Survey data were obtained by use of a mailed questionnaire to 500 high income cattle farmers in the state of Illinois. Agriculture advertisers wishing to reach a similar highly selective market can adopt this survey procedure to determine demographic characteristics, information for the farm market and the value of this information to the farmer. Frequency counts will be obtained on most of the data and multiple correlations made between the aforementioned variables. Results will be included as major part of a masters thesis. (Bill Engelbrecht)

2690-76068 Civil Engineering. Stream Reaeration. The problem is an investigation of stream reaeration rates using modifications of the Streeter-Phelps reaeration equation. The objective is to determine the variation of dissolved oxygen levels in streams when various parameters are used in the equations. The solutions to these differential equations will be programmed and parameters from previous research and stream tests will be used to determine dissolved oxygen levels. The computer results will then be used to determine what parameters and what parameter values have the greatest effect on the dissolved oxygen levels. (K. U. Hansen)

2691-76069 Civil Engineering. Study of Biochemical Oxygen Demand in Aerated Lagoons. We intend to analyze some of the data available in the literature on Biochemical Oxygen Demand (BOD) removal in Aerated Lagoons. We will obtain a least square fit on the data on %BOD removal vs. time, θ, and obtain plots of θ/E vs. θ (where E is %BOD removal in the Aerated Lagoon) which may be linear. The future course of analysis will depend on the characteristics of the plots thus obtained. (R. I. Dick)

2692-76070 T Political Science. A Quantified Application of Group Theory to National Politics. "A Quantified Application of Group Theory to National Politics" is a thesis topic focusing on the relationship between voting blocs in the United States House and Senate and organized groups lobbying Congress. The voting blocs within Congress will be located through analysis of roll call votes stored on data cards obtained from the Survey Research Center of the University of Michigan. The data on interest groups are being collected from reports in newspapers and other periodicals and coded for storage on data cards. The mathematical techniques contained in SSUPAC, such as Multiple Discriminant Analysis to be used to locate voting blocs and Missing Data Correlations to be used to measure the degree of association between voting blocs and interest group positions, will be sufficient for purposes of this research. The results of this largely correlational analysis will be used to test the adequacy of group theory based on qualitative analysis. (Edward Malecki)

2693-76071 T Astronomy. Radio Source Counts in Curved Universes. A formula giving the number of extragalactic radio sources which are stronger than a given flux density is integrated. A Gaussian luminosity distribution is assumed, together with a simple form of luminosity evolution. The integrations are carried out using Simpson's Rule. The purpose of the problem is to compare the results obtained for various curved, uniform model universes with the results which have previously been obtained for the flat Einstein - deSitter universe. (Richard Ringenberg)

2694-76072 T Theoretical and Applied Mechanics. Computerized Processing of Photoelastic Data. The basic topic studied here is Scattered Light Photoelasticity, which is an experimental means of measuring stress. The computer plays its role as a slide rule. The data obtained through experimental procedures is not in usable form. The processing of this data can be expedited through use of the computer. One of the operations required is a numerical integration of the equilibrium equations of elasticity. A least squares fit of the data is also necessary. Finally, a comparison between experimental and theoretical results is necessary. (John Martin)

2695-76073 T Physical Education for Men and Graduate PE. Achievement Orientation and Its Affect on the Structure of the Social System of the School Class. An attempt is made to discern what influence performance has on the structure of the social system of a school class. The question of which social factors performance is dependent on has been pursued in sociology, but studies using performance as an independent variable have not been carried out. In this study, boys at the "gang age" and in 11 physical education classes were used. Sociometric tests were employed in order to discern the liking structure, leadership structure, rankings in physical activity ability and academic ability. The tests were given before, immediately after, and a month after the application of the dependent variable achievement orientation, was applied. It is proposed that Spearman's rank correlation coefficient, Kendall's rank correlation coefficient and Kendall's coefficient of concordance will be used. (G. M. McKelvey)

10.2 Instructional Problem Specifications

During the second quarter of 1967, 4 instructional problem specifications were submitted to the department for computation. The following brief descriptions of these problems have been prepared for inclusion in this report by those submitting them.

I670-74041 Agricultural Economics 230. Business Management Simulation. This business management simulation is used to teach students the effect of their decisions as managers of a simulated business in a competitive and dynamic environment. The computer is used to make the necessary computations that provide the simulated environment. A secondary objective is to make students familiar with the basic financial statements of a business and to show them how to use these instruments in business management. The printout of the program is in the form of standard financial statements. (R. P. Bentz)

I675-74064 Educational Psychology 312. Marital Difficulty and Mental Health. The problem is to determine relationships between age, sex, education, and answers to various marital questions. The analysis will include regression or correlation analysis. (R. Stewart Jones)

I677-75016 Political Science 497. Research Design and Techniques. Political Science 497 is a seminar in quantitative methods. It is designed to acquaint the student, on a first hand basis, with empirical political analysis. This means that the student must submit data for manipulation by standard statistical routines. Students gain competence in selecting appropriate routines, learning the mechanical procedures of calling or writing routines, and learning how to interpret the manipulations of the data. The current batch of data that students are working with is from the University of Michigan's Survey Research Center. The data were supplied by the Inter-University Consortium for Political Research through the good offices of the Survey Research Laboratory's Data Repository. (A. H. Miller)

I687-76039 Agricultural Economics 491. Agricultural Applications of Linear Economic Models. Students will be assigned six class problems; all will be linear programming problems. Students will work in groups of three or four. A total of about 20 problems will be run. LPG1 will be used. This is an adaptation of SHARE program #1037-SCM2. (E. R. Swanson)

10.3 Blanket Class Problem Specifications

During the second quarter of 1967, 23 problem specifications were submitted to over all assigned problems in the following courses.

J667-74007 Graduate School of Business Administration 531.

J668-74013 Mechanical Engineering 407.

J669-74014 General Engineering 288.

J671-74042 Nuclear Engineering 458.

J672-74043 Sociology 386.

J673-74044 Civil Engineering 262.

J674-74055 Political Science 441.

J676-75003 Music 320.

J678-75056 Mechanical Engineering 264.

J679-75057 Mechanical Engineering 263.

J680-76017 Agronomy 493.

J681-76018 Civil Engineering 391.

J682-76021 Computer Science 387.

J683-76027 Computer Science 101.

J684-76029 Nuclear Engineering 490.

J685-76037 Graduate School of Business Administration 544.

J686-76038 Graduate School of Business Administration 545.

J688-76040 Electrical Engineering 498.

J689-76041 Graduate School of Business Administration 531.

J690-76044 Music 440.

J691-76052 Electrical Engineering 323.

J692-76058 Civil Engineering 461.

J693-76063 Accountancy 373.

11. GENERAL LABORATORY INFORMATION

11.1 Personnel

The number of people associated with the Laboratory in various capacities is given in the following table:

	Full-time	Part-time	Full-time Equivalent
Faculty	15.0	2.0	16.0
Visiting Faculty	3.0	0.67	3.67
Research Associates	2.0	---	2.0
Graduate Research Assistants	4.0	82.0	43.4
Professional Personnel	18.0	1.25	19.25
Administrative and Clerical	20.0	2.0	21.0
Nonacademic Personnel (Monthly)	68.0	2.0	69.0
Nonacademic Personnel (Hourly)	4.0	116.0	43.0
TOTAL	134.0	205.92	217.32

The Computer Science Advisory Committee consists of Professor J. R. Pasta, Head of the Department; Professor J. N. Snyder, Associate Head of the Department; Professors L. D. Fosdick, H. G. Friedman, C. W. Gear, D. B. Gillies, D. J. Kuck, B. H. McCormick, S. Muroga, T. A. Murrell, J. Nievergelt, W. J. Poppelbaum, S. R. Ray, J. E. Robertson, and D. L. Slotnick.

11.2 Bibliography

During this quarter, the following publications were issued by the Laboratory.

File Numbers

(1) Gear, C. W. and Carter, C. E., "Design Principles for an Active Remote Terminal," File No. 732, May 5, 1967.

(2) Lukaszewicz, Leon, "Outline of EOL Language," File No. 733, June 20, 1967.

(3) Lukaszewicz, Leon, "Language XI," File No. 734, June 22, 1967.

(4) McCormick, B. H., "Present Status of the ILLIAC III," File No. 730, April 3, 1967.

(5) "Status Report: AEC Information Meeting," Rice University, Houston, Texas, April 3, 1967.

Specification Numbers

(1) Amendola, R. C., "Specifications for a Microfilm Processor," File No. 550-99, May 22, 1967.

(2) Casasent, David, "Specification for Laser Analyzer Prism," File No. 550-95, April 24, 1967.

(3) Casasent, David, "Specifications for Beam Shutter and Supply," File No. 550-96, April 24, 1967.

(4) Casasent, David, "Specifications for Pulse Generator," File No. 550-97, April 24, 1967.

(5) Casasent, David, "Specification for Beam Shutter," File No. 550-98, April 24, 1967.

(6) Casasent, David and Sand, Douglas, "Specifications for X-Y Recorder," File No. 550-101, May 18, 1967.

(7) Oberbeck, Peter, "Specifications for Highspeed A/D Converter," File No. 550-94, April 24, 1967.

Report Numbers

(1) Bond, W. D., Davidson, E. S., and McCormick, B. H., "The Web System. Part II: A Formal Description of the WEB Input Language," Report No. 232, June 19, 1967.

(2) Bond, W. D. and Davidson, E. S., "The WEB System. Part III: Web Change Orders," Report No. 233, June 19, 1967.

(3) Ray, S. R., "Prospects and Problems in Designing Image Oriented Information System," Report No. 224, May 8, 1967.

Theses

(1) Atkins, Daniel E., III, "The Theory and Implementation of SRT Division," (M.S.), Report No. 231, June 1, 1967.

(2) Cederquist, Gerald N., "An Input-Output System for a Multiprogrammed Computer," (M.S.), Report No. 223, April 24, 1967.

(3) Chan, Shiu Kwong, "Communication Net of Modular Processors for a Multiprocessor Computer," (M.S.), Report No. 231, June 1, 1967.

(4) Hayes, John P., "A Content Addressable Memory with Applications to Machine Translation," (M.S.), Report No. 227, June 1, 1967.

(5) Hoffman, Donald Jay, "Optimizing Feedback Conditions in a Phase Shift Oscillator," (M.S.), Report No. 225, May 16, 1967.

(6) Rohatsch, Fred A., "A Study of Transformations Applicable to the Development of Limited Carry-Borrow Propagation Adders," (Ph.D.), Report No. 226, June 1, 1967.

(7) Selleck, James E., "Switching-Mode Audio Amplifier," (M.S.), Report No. 229, June 1, 1967.

(8) Slivinski, Thomas Andrew, "Partially Separable Functions," (Ph.D.), Report No. 228, June 1, 1967.

11.3 Numerical Analysis

"Error Bounds for Direct Solution of Linear Equations," by Professor D. B. Gillies, Department of Computer Science, University of Illinois, Urbana, Illinois, April 4, 1967.

"Alternating Direction Implicit Method Used in Connection with Illiac IV," by Mr. Lawrence Rudsinski, Department of Computer Science, University of Illinois, Urbana, Illinois, April 11, 1967.

"Calculation of Bessel Functions over Large Ranges of Argument and Order, Part I," by Mr. Peter Alsberg, Department of Computer Science, University of Illinois, Urbana, Illinois, April 18, 1967.

"Calculation of Bessel Functions over Large Ranges of Argument and Order, Part II," by Mr. Peter Alsberg, Department of Computer Science, University of Illinois, Urbana, Illinois, April 25, 1967.

"Variable Successive Over-Relaxation - I," by Mr. Leland McDowell, Department of Computer Science, University of Illinois, Urbana, Illinois, May 2, 1967.

"Continuation of Solutions to Higher Order Elliptic Equations," by Mr. Paul Saylor, Department of Mathematics, Rice University, Houston, Texas, May 9, 1967.

"Variable Successive Over-Relaxation - II," by Mr. Leland McDowell, Department of Computer Science, University of Illinois, Urbana, Illinois, May 16, 1967.

"Matrix Algebra Techniques on the Illiac IV," by Mr. Pierre Blondeau, Department of Computer Science, University of Illinois, Urbana, Illinois, May 23, 1967.

11.4 Colloquia

"Covering Problems in Combinatorial Computing," by Dr. Mark B. Wells, University of California, Los Alamos Scientific Laboratory, April 3, 1967.

"Pattern Recognition Using $N^{\underline{th}}$ Order Autocorrelation Functions," by Dr. John A. McLaughlin, IBM Watson Laboratory, Yorktown Heights, New York, April 24, 1967.

"Why Do Meteorologists Need a Big Computer," by Professor Eberhardt Wahl, University of Wisconsin, Madison, Wisconsin, May 1, 1967.

"An Associative Processor," by Dr. Tse-yun Feng, Department of Electrical Engineering, University of Michigan, Ann Arbor, Michigan, May 8, 1967.

"Picture Processing via Generalized Superposition," by Dr. Thomas G. Stockham, Lincoln Laboratories, Lexington, Massachusetts, May 15, 1967.

"An Extension of Threshold Logic to Include Partially Separable Functions," by Mr. Thomas A. Slivinski, Department of Computer Science, University of Illinois, Urbana, Illinois, May 22, 1967.

"Algebraic Formula Manipulation on a Computer," by Professor Max Engeli, University of Texas, Department of Computer Science, Austin, Texas, May 26, 1967.

"Building Blocks for Everyman: The Macro-modular Approach," by Dr. Wesley A. Clark, Medical Center, Washington University, St. Louis, Missouri, May 29, 1967.

11.5 Drafting

During the second quarter, a total of 842 drawings were processed by both drafting sections:

	General	Pattern Recognition
Large Drawings	28	23
Medium Drawings	441	19
Small Drawings	25	19
Layouts	3	190
Report Drawings	0	59
Changes	20	9
Miscellaneous	6	0
TOTAL	523	319

(M. Goebel and J. Otten)

11.6 Shops' Production

Job orders processed and completed during the second quarter of 1967, are as follows:

FACILITY	STATE 300	AEC 1018	AEC 1469	AEC 1834	OTHER
Machine Shop	19	24	18	16	4
Electronics Shop	0	81	24	9	0
Etch Shop	8	29	24	8	6
Layout Shop	2	12	22	9	0

Wiring of 2,206 standard printed circuit boards and 775 baby boards during this period accounted for 137,904 diodes and 36,225 transistors, and 50 1018-1664 Mother Board Assemblies were assembled.

Frank P. Serio

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